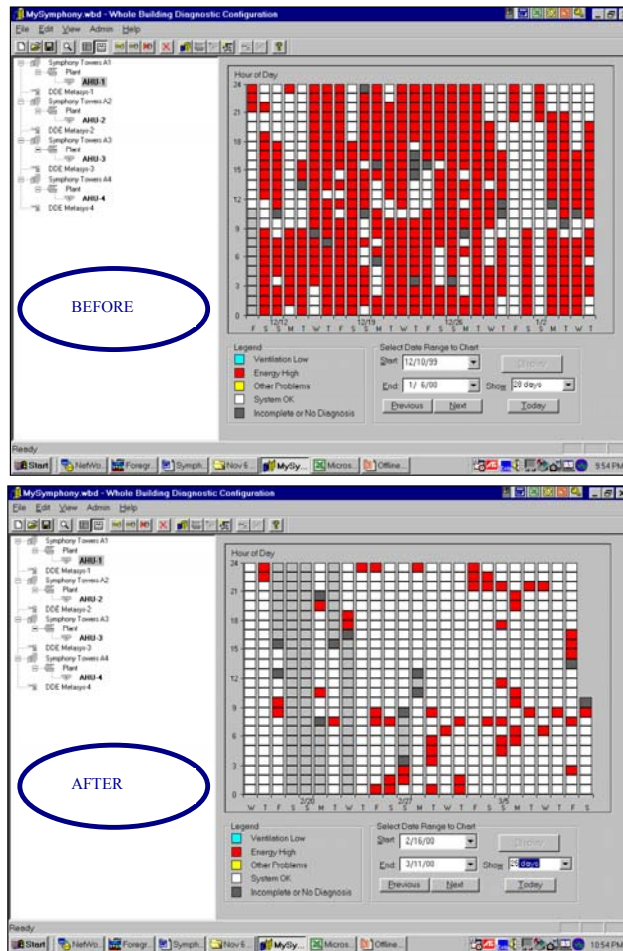


Final Report Compilation for Enhancement of the Whole Building Diagnostician



TECHNICAL REPORT

October 2003
P-500-03-096-A6



Gray Davis, Governor

CALIFORNIA ENERGY COMMISSION

Prepared By:
Architectural Energy Corporation
Vernon A. Smith
Boulder, CO

Battelle Memorial Institute
Northwest Division
David Chassin
Michael Brambley
Richland, WA

CEC Contract No. 400-99-011

Prepared For:
Christopher Scruton
Contract Manager

Nancy Jenkins
PIER Buildings Program Manager

Terry Surles
PIER Program Director

Robert L. Therkelsen
Executive Director

DISCLAIMER

This report was prepared as the result of work sponsored by the California Energy Commission. It does not necessarily represent the views of the Energy Commission, its employees or the State of California. The Energy Commission, the State of California, its employees, contractors and subcontractors make no warrant, express or implied, and assume no legal liability for the information in this report; nor does any party represent that the uses of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by the California Energy Commission nor has the California Energy Commission passed upon the accuracy or adequacy of the information in this report.

Acknowledgements

Michael Brambley and David Chassin with Battelle Memorial Institute, Northwest Division, led the research team.

Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The Program's final report and its attachments are intended to provide a complete record of the objectives, methods, findings and accomplishments of the Energy Efficient and Affordable Commercial and Residential Buildings Program. This attachment is a compilation of reports from Project 2.6 *Enhancement of the Whole Building Diagnostician*, providing supplemental information to the final report (Commission publication #P500-03-096). The reports, and particularly the attachments, are highly applicable to architects, designers, contractors, building owners and operators, manufacturers, researchers, and the energy efficiency community.

This document is one of 17 technical attachments to the final report, consolidating three research reports from Project 2.6:

- [*Instructions for Installation of the Whole-Building Diagnostician Software Release 2.10-162 \(Aug 2003\)*](#)
- [*Instructions for Configuration of the Whole-Building Diagnostician Software Release 2.10-162 \(Aug 2003\)*](#)
- [*Whole Building Energy Enhancement Report PNWD 3317 \(Aug 2003\)*](#)

The Buildings Program Area within the Public Interest Energy Research (PIER) Program produced this document as part of a multi-project programmatic contract (#400-99-011). The Buildings Program includes new and existing buildings in both the residential and the nonresidential sectors. The program seeks to decrease building energy use through research that will develop or improve energy-efficient technologies, strategies, tools, and building performance evaluation methods.

For the final report, other attachments or reports produced within this contract, or to obtain more information on the PIER Program, please visit www.energy.ca.gov/pier/buildings or contact the Commission's Publications Unit at 916-654-5200. The reports and attachments, as well as the individual research reports, are also available at www.archenergy.com.

Abstract

Project 2.6, *Enhancement of the Whole Building Diagnostician.*

Project 2.6 provided a significant improvement to the WBD. Increases or decreases in whole building, or building systems, electrical or gas energy use may be caused by system faults or changes in occupant activity. For example, energy use will increase with increased sales in a restaurant, but it will decrease if an HVAC unit went off line due to compressor failure. The Whole Building Energy (WBE) module of the Whole Building Diagnostician, which is designed to flag anomalies in energy use patterns, was improved with changes to allow it to be used on a wide spectrum of building types.

- The added feature allows the user to specify any BAS variable or other accessible variable (such as sales volume) as one of up to five independent variables in the WBE module. The previous versions allowed only outside air temperature, outside humidity, and building schedule as independent variables. This will allow operators of similar buildings, such as chain retail stores and restaurants, to compare energy performance and spot positive and negative trends over time. The value to California chain managers could be a significant motivating factor to use or install energy management control systems.
- Methods and user interfaces for a second planned improvement, a module for energy use comparisons among peer buildings that could be used in near real time, were developed and partially implemented, but full implementation was not possible because of a second-year lapse of co-funding.

This document is a compilation of three technical reports from the research.

Energy Efficient and Affordable Small Commercial and Residential Buildings Research Program

a Public Interest Energy Research Program

sponsored by the California Energy Commission and the U.S. Department of Energy Office of Building Systems, State and Community Programs

Instructions for Installation of the Whole-Building Diagnostician Software Release 2.10-162

Project 2.6 – Enhancement of the Whole Building Diagnostician

Task 2.6.3 – Installation Instructions

Teresa A. Carlon
Nathan N. Bauman

August 2003

Prepared for
Architectural Energy Corporation

Battelle Northwest Division
Richland, Washington 99352

THIS REPORT WAS PREPARED AS A RESULT OF WORK SPONSORED BY THE CALIFORNIA ENERGY COMMISSION (COMMISSION). IT DOES NOT NECESSARILY REPRESENT THE VIEWS OF THE COMMISSION, ITS EMPLOYEES, OR THE STATE OF CALIFORNIA. THE COMMISSION, THE STATE OF CALIFORNIA, ITS EMPLOYEES, CONTRACTORS, AND SUBCONTRACTORS MAKE NO WARRANTY, EXPRESS OR IMPLIED, AND ASSUME NO LEGAL LIABILITY FOR THE INFORMATION IN THIS REPORT; NOR DOES ANY PARTY REPRESENT THAT THE USE OF THIS INFORMATION WILL NOT INFRINGE UPON PRIVATELY OWNED RIGHTS. THIS REPORT HAS NOT BEEN APPROVED OR DISAPPROVED BY THE COMMISSION NOR HAS THE COMMISSION PASSED UPON THE ACCURACY OR ADEQUACY OF THE INFORMATION IN THIS REPORT.

Installation and Configuration Instructions for the Whole-Building Diagnostician Software Release 2.10-162

Welcome to the Whole-Building Diagnostician™ (WBD) Software tool developed by a U.S. Department of Energy (DOE) team led by Pacific Northwest National Laboratory¹ (PNNL) and enhanced under funding from the California Energy Commission (CEC) and the U.S. Department of Energy. The WBD is modular diagnostic software that detects and diagnoses common problems associated with heating, ventilating, and air-conditioning (HVAC) systems and equipment. The software has two modules--one to monitor whole-building energy use (the whole-building energy module or WBE) and one to detect and diagnose problems associated with outdoor-air control and economizer operation in air-handling units (AHUs) (the outdoor air and economizer module or OAE).

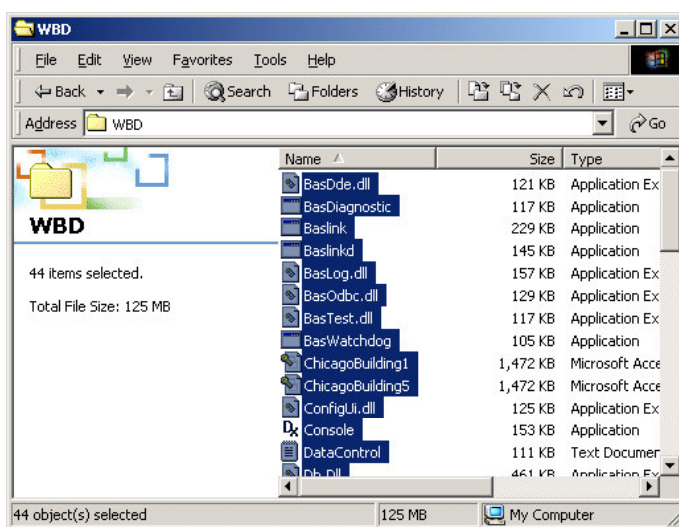
The CD for the Enhanced Version contains an executable version of the WBD 2.10-162 software plus a database for viewing a set of representative WBE results. This version includes new features of the WBE module developed as part of the Energy Efficient Buildings Research Program of the California Energy Commission.

This instruction document describes how to install the WBD and the Microsoft Data Access Object® (DAO) components, how to view the results in the demo database, and the new features of the WBE. If you are upgrading or reinstalling the WBD, you do not need to install Microsoft DAO but should follow the instructions for *Preparing to Install the Enhanced WBD, Release 2.10-162*.

Preparing to Install the Enhanced WBD, Release 2.10-162

Because Build 162 of the WBD incorporates changes to the underlying WBD database, it is easiest to delete previous versions of the WBD from your computer before installing this version.

1. To remove earlier versions of the WBD, navigate to the C:/Programs/WBD subfolder on your hard disk (if you used the default directory when installing the WBD previously) or the alternate folder in which you installed previous versions of the WBD.
2. Highlight all files in this directory using your mouse and then push the "Delete" key.



¹ Operated for U.S. DOE by Battelle.

- The dialog box at right will appear. Click **"Yes."** This should delete all files for previously installed versions of the WBD. You are now ready to install Release 2.10-162.



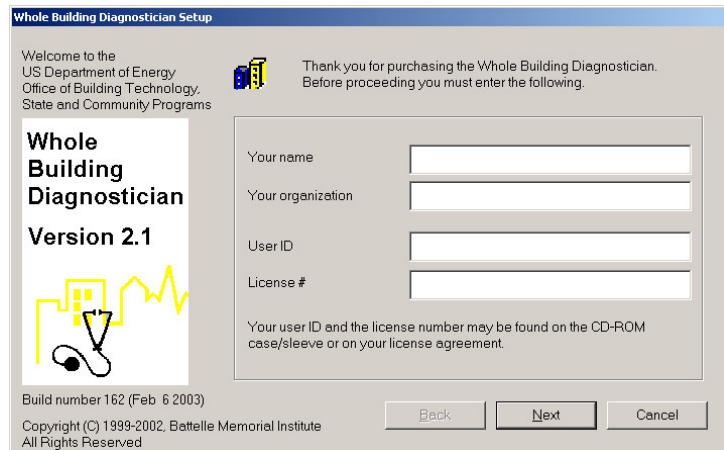
Installation Instructions for the Whole-Building Diagnostician Software



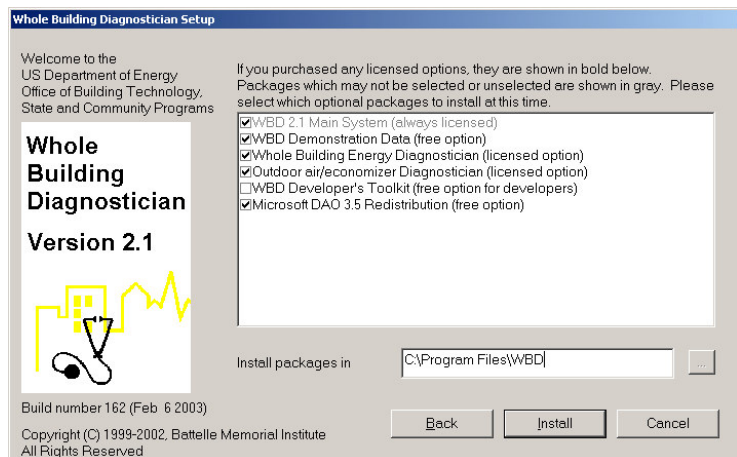
Whole-Building
Diagnostician

- To install the Whole-Building Diagnostician (WBD) software, insert the WBD 2.10-162 installation CD into your CD-ROM drive. The setup program should run automatically. If the setup program fails to run automatically, use the Windows Explorer (in Windows 95) or My Computer (in Windows 98 or higher) to navigate to the CD-ROM drive on your computer, find the program **"setup.exe,"** and double click on it. This will start the installation process.

- Follow the steps provided by the installation wizard. You will need to provide your User ID and License number, which can be found on the back of the CD case. Click **"Next"** when finished.

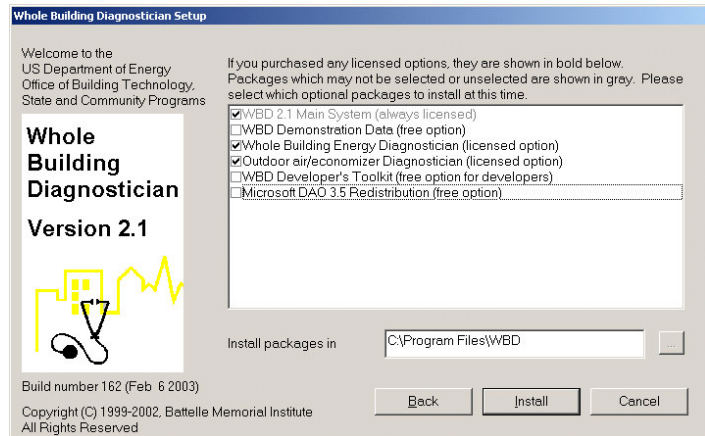


- Next the installation wizard will give you several "component installation" choices. The components available are based on your software license. Select the components you wish to install now by clicking on them (you should then see a check mark before each component selected).



By default, the WBD will be installed in "C:\Program Files\WBD." Typing a new directory name and path in the white area near the bottom of the page will change this directory.

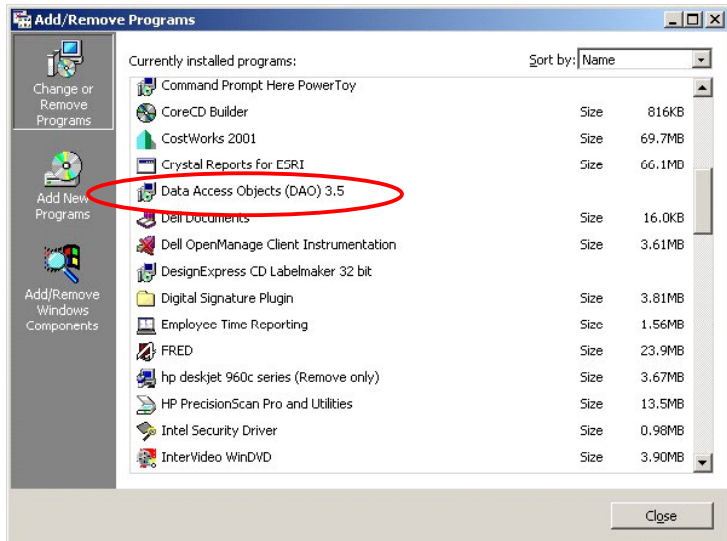
The WBD software (executable, dynamic link library, and ancillary files) needs less than 10 Mbytes of space on your hard disk. The demonstration databases, however, need approximately 100 Mbytes of disk space, so the total required for initial installation of the WBD plus demonstration databases is about 110 Mbytes. These files must all be installed in the same directory.



7. The WBD requires Microsoft DAO 3.5 installed on your computer in order to run. If you already have DAO 3.5 installed, you do not need to install it again. To determine if you have it installed, do the following: from the Start button, select "Settings" and then "Control Panel." On the "Control Panel", double click on the **"Add/Remove Programs"** icon. The dialog box at right (or one very much like it in Windows NT or XP) will appear. If this dialog box is not already showing, select the "Install/Uninstall" tab (or "Change or Remove Programs" in Windows 2000). Check the list of programs installed. If Data Access Object 3.5 is not on the list, you will need to install it; proceed to step 10. If DAO 3.5 is on the list (already installed), continue to step 8.

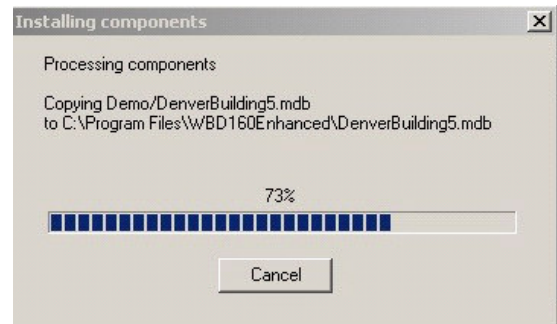


Add-Remove Programs

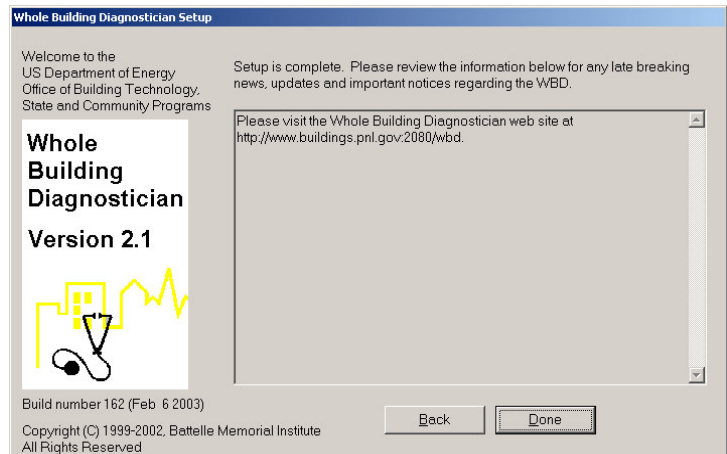


8. After selecting the components and installation directory, click on the **"Install"** button to begin copying files.

You will see the progress window at right during installation.



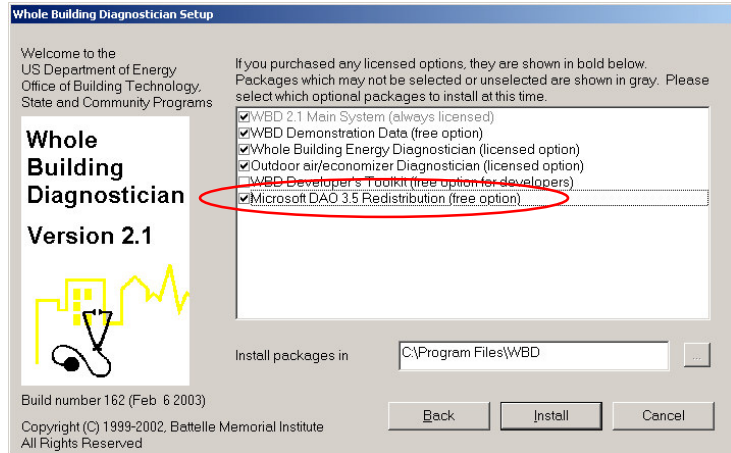
9. The screen at right will display when installation is complete. Click on the **"Done"** button to leave the installation program. You are now ready to start using the WBD. For instructions, please refer to the "Viewing the Demonstration Database" and "Exploring the Enhanced WBE Features" sections later in this document. Skip to step 14, *Viewing the Demonstration Database*.



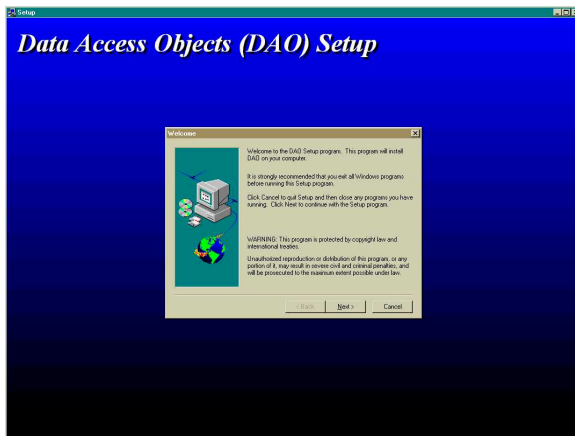
Installation Instructions for Microsoft DAO

These instructions should be followed, only if in step 7 you found that you do not have Microsoft DAO 3.5 already installed.

10. On the component selection screen, make sure you select the "Microsoft DAO 3.5" box. After selection, a check mark should appear in the box. After you have selected all licensed components that you want to install now (see step 6 for additional guidance), click on **"Install."**



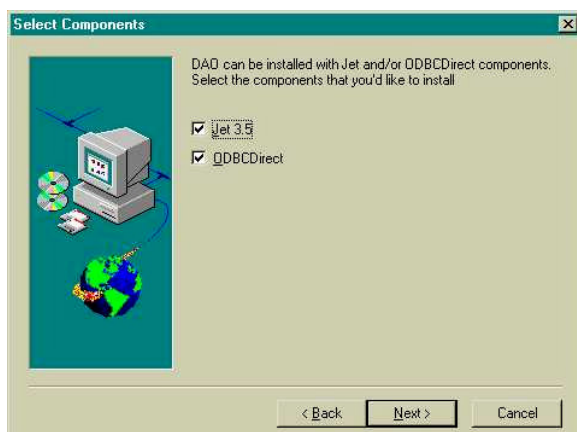
11. During the DAO installation, a sequence of dialog boxes will appear in the "Data Access Objects (DAO) Setup" window. Do not change any entries in these dialog boxes. Simply click the **"Next"** button to reveal the next dialog box. If any additional dialogs appear during installation, click **"OK"** or **"Next"** to continue installation.



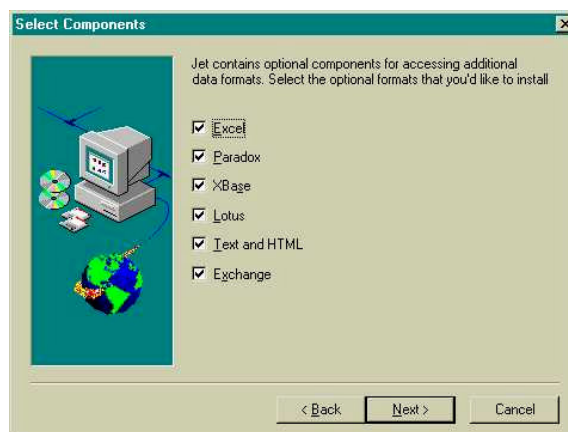
Click **"Next"**



Click **"Next"**

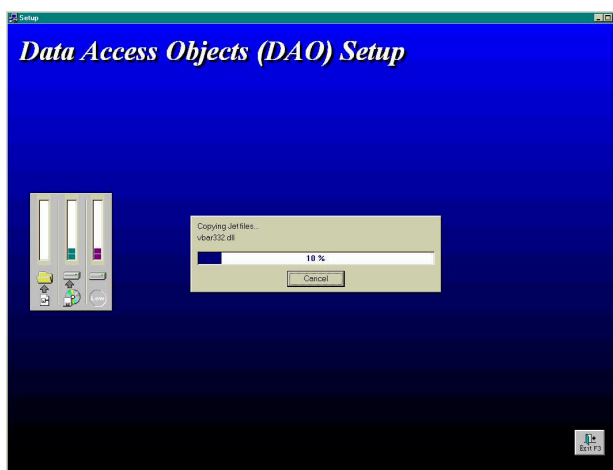


Click "**Next**"

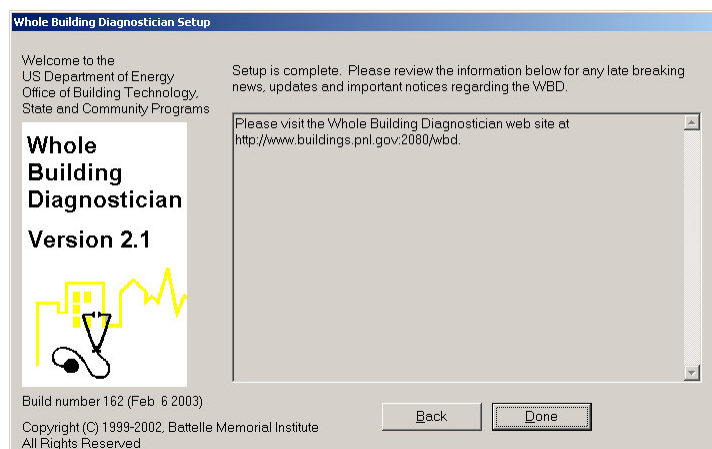


Click "**Next**"

12. After clicking "Next" on the last dialog, a progress indicator will appear in the "Data Access Objects (DAO) Setup" window. If any additional dialogs appear during installation, click "OK" or "Next" to continue installation. When installation of the DAO is complete, a Windows information box will appear with the message "Data Access Objects (DAO) successfully installed." Click on the "OK" button.



13. The WBD installation program will then display the window at right indicating that installation is complete. Click on the "Done" button to leave the installation program. You are now ready to start using the WBD. Please refer to the "Viewing the Demonstration Database" and "Exploring the Enhanced WBE Features" sections of this document, which follow.

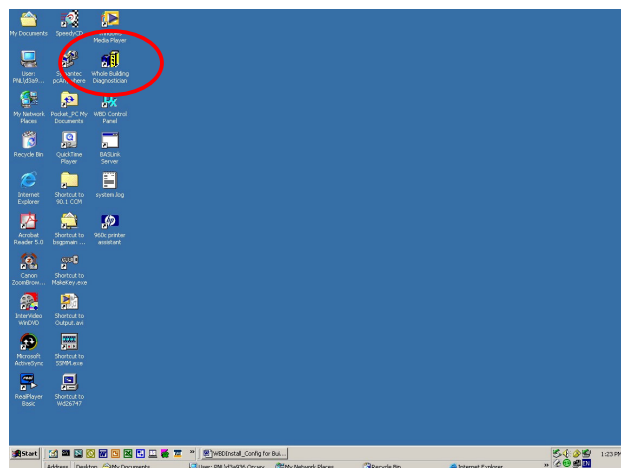


Viewing the Demonstration Database

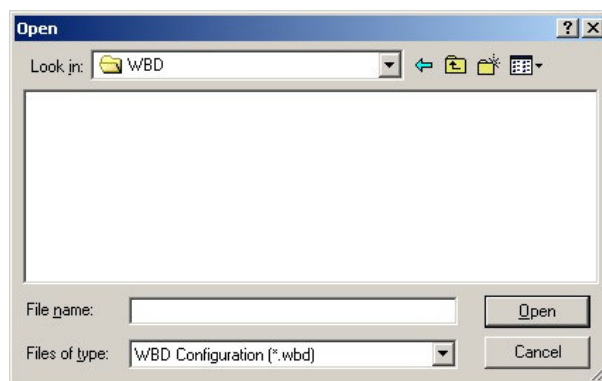
The enhanced version of the WBD contains a database for viewing a set of representative results and examining the new features of the WBD module developed as part of the Energy-Efficient Buildings Research Program of the Energy Commission. To create a new database, see the companion document *Instructions for Configuration of the Whole-Building Diagnostician Software Release 2.10-162*.

After successfully installing the WBD and the Microsoft DAO[®], the WBD can be used to process new data or view processed results. These instructions will help you start exploring the enhanced version of the WBD.

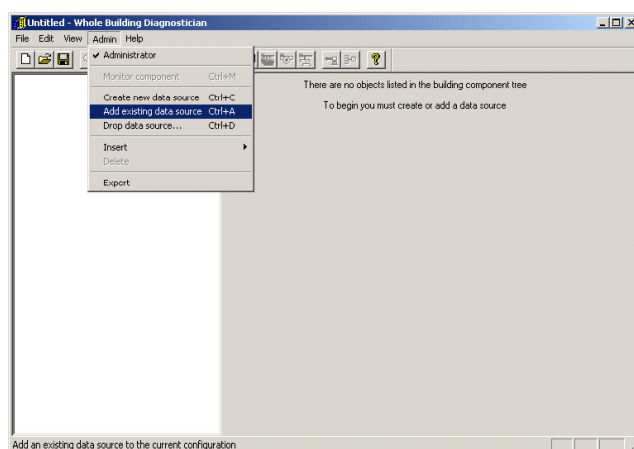
14. To run the WBD, double-click on the **WBD** shortcut icon on your desktop. You may also launch the WBD by navigating to the directory in which the WBD was installed and double clicking on the file named "WBD."



15. Once the WBD is launched, the dialog box shown to the right should appear. Click "**Cancel**."

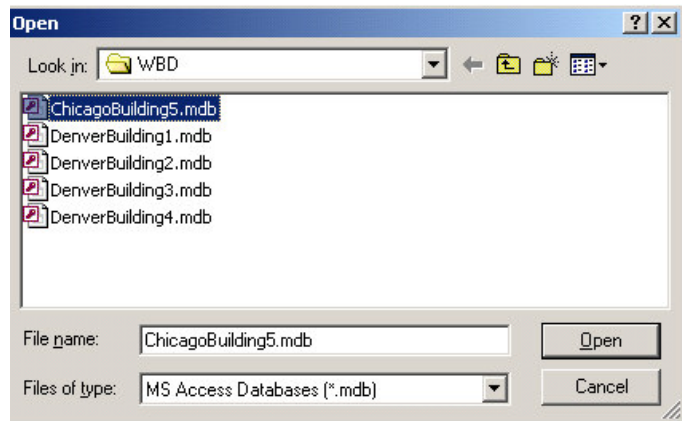


16. The window at right will appear. On the "**Admin**" pull down menu, click on "**Add existing data source**."

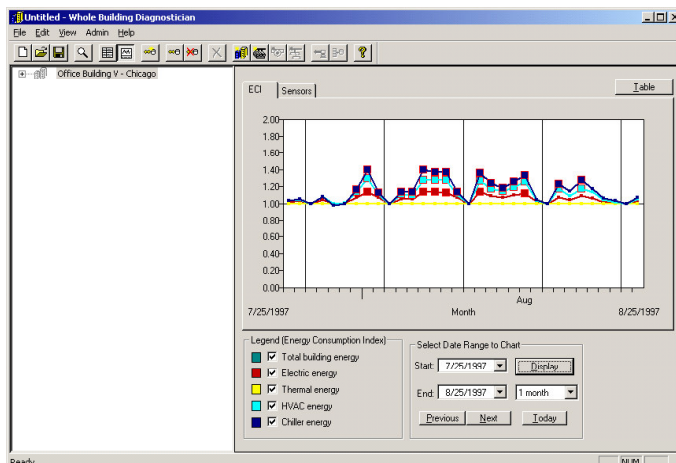
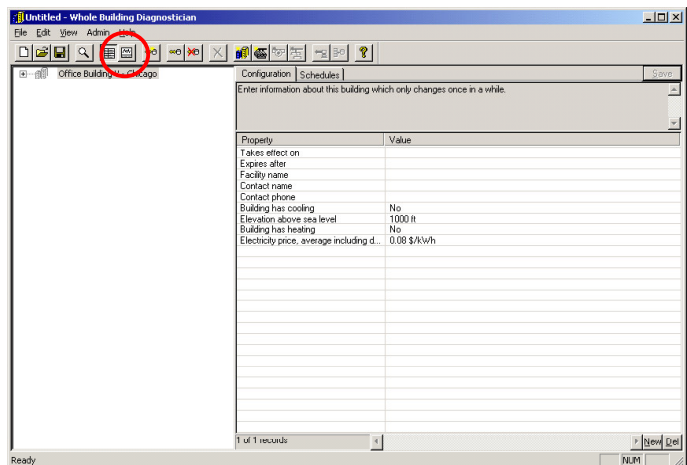


17. The “Open” dialog box will appear. This will list all the Microsoft Access® databases that are present in the WBD installation directory. For the WBE demonstration, click on the database name **ChicagoBuilding5.mdb** to highlight it. Then click “Open.”

If the demonstration database is installed in a directory other than the WBD installation directory, including the case where it was not installed but is on your CD-ROM, navigate to that directory (as you would normally to explore files). If using demo data from the CD, select the "Demo" subdirectory on the CD. To select the demonstration database, click on its name, then click "Open."



18. After selecting the database, a window like the one to the right will appear. This window is a WBD setup screen, which is used for configuring the software for a new building or equipment that will be monitored with the WBD. Click on the icon identified by the red circle, “View diagnostic results”.



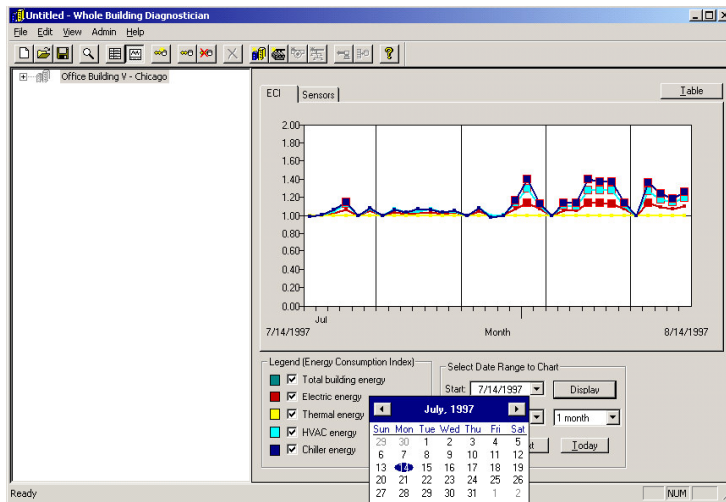
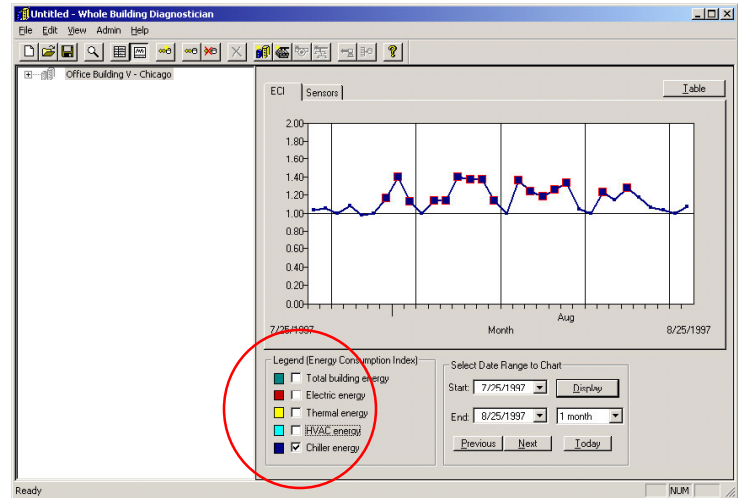
19. This will change the window to the one displayed on the right. The left panel of this window provides a tree of all buildings and equipment identified in the databases selected, in this case only the WBE Demo building. The right panel of the window shown here is the graphic display for the WBE module. If the data shown in the graph at right do not display, click on all of the check boxes in the Legend. The data will then display. You are now ready to

explore features of the WBE.

The graph shows values of the Energy Consumption Index (ECI) for each day of the time period displayed. A separate ECI is shown for each of the five energy uses, which are identified by color coding in the Legend. The ECI is the ratio of actual energy use to the expected energy use. The expected energy use is determined by an empirical model in the WBE software for each tracked energy use. A value of each of the ECIs is shown for each day in the range displayed. Values of the ECI around 1.0 indicate that the building and its energy systems are performing as expected. Values substantially different than 1.0 indicate an energy-use anomaly.

20. The specific energy uses for which ECIs are displayed can be changed by clicking on the check boxes in the Legend to select and deselect energy uses. As an example, the window at the right shows only the chiller energy.

The squares appearing on the graph are used to identify when a statistically significant aberration in energy consumption (high or low) has occurred. For the chiller energy use in this plot, 16 days had high values of chiller energy use.



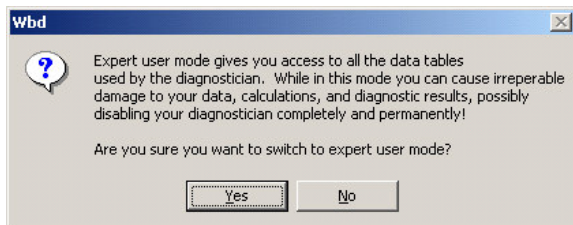
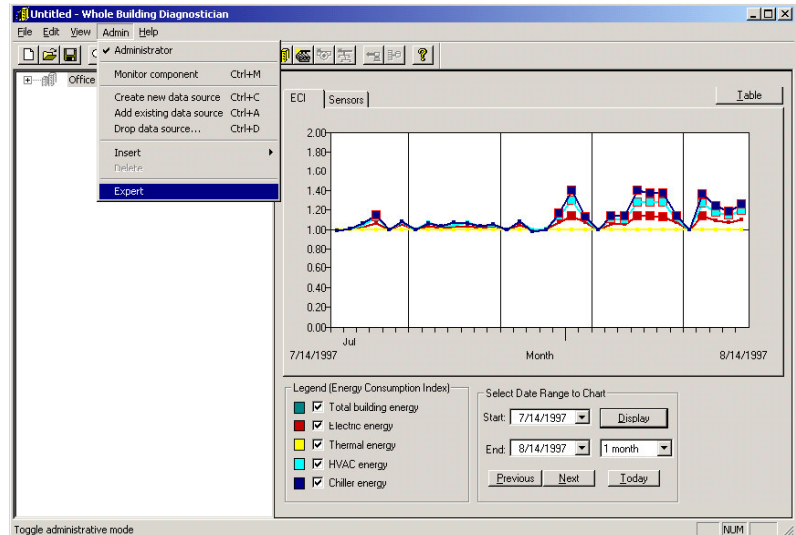
21. The dates for which data are displayed can be changed simply by clicking on the **“Previous”** or **“Next”** buttons in the **“Select Date Range to Chart”** panel below the graph. The length of the time period displayed can be changed by clicking on the arrow appearing immediately after **“1 month”** (in the current display) and then selecting the desired time-period length from the drop-down menu. Specific Start and End dates for the data range can also be

selected, as shown in the figure at the right. Click on the arrow to the right of the start date. A calendar box will appear. Click on July 14 to select it as the new start date.

Exploring the Enhanced WBE Features

To examine the enhanced modeling features of the WBE module, perform the following steps.

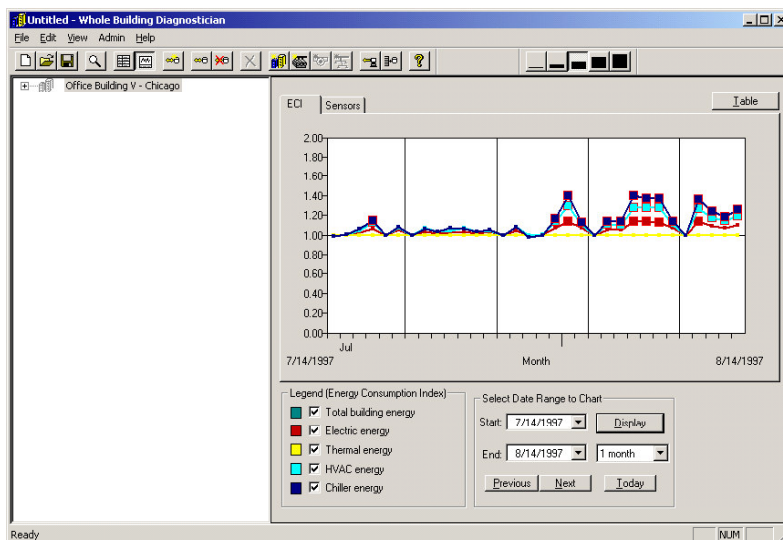
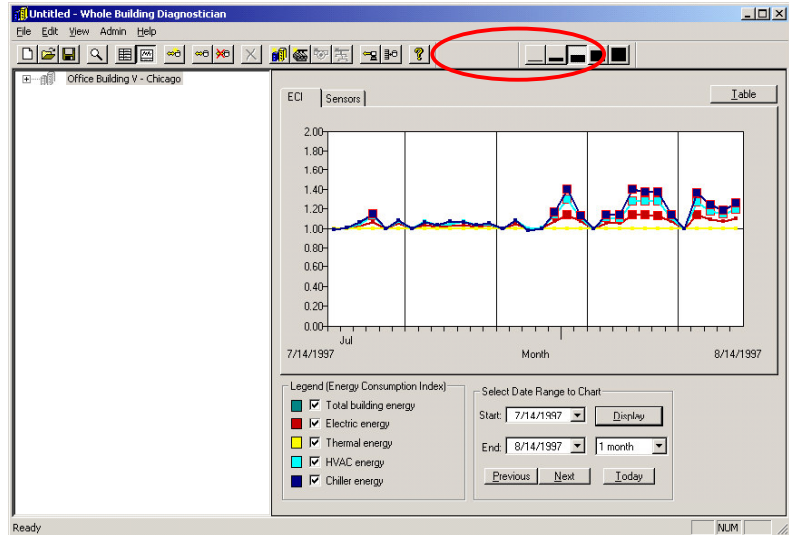
22. Click on **“Admin”** on the menu bar and then select **“Expert”** from the drop-down menu.



23. The dialog box shown at right will appear. Click **“Yes.”** You will then be in the Expert mode, which can only be assigned by an Admin. Ordinary users do not have Admin privileges, unless assigned by someone who already has Admin privileges. Generally, a site would have only one or two Admin users who would administer the system by selecting and changing (when desired) general settings, specifying the empirical models, setting time periods for baseline data, and performing other administrative functions, which would then apply for all users at the site.

The features added as part of the Energy Commission project to enhance the WBE are some of those available to an Admin user who has selected to enter the “Expert” user mode. This demonstration software has been distributed to you with Admin privileges so you can examine the enhanced modeling features of the WBE.

24. When you entered “Expert” mode, you should have noticed a small rectangle with five buttons in it, appearing somewhere on your screen. This box is circled in the figure on the right. Click on this box, hold the mouse button, and drag the box to the position on the tool bar shown at right. Release the mouse button, and the small box will become part of the tool bar, as shown.

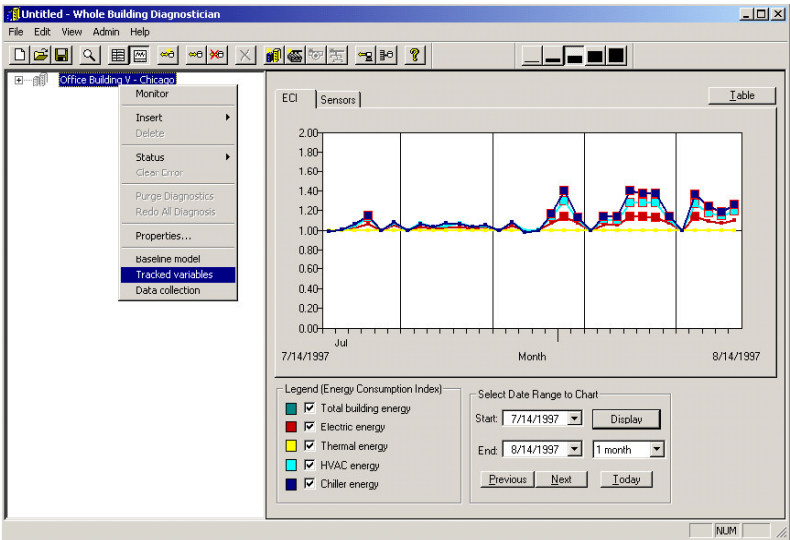


25. The buttons in the box are diagnostic sensitivity controls. The left-most button makes the WBE least sensitive, and the right-most button assigns it the maximum sensitivity. Click on the right-most button and observe the increase in the number of “alarm” boxes appearing on the graph. The sensitivity of the system to energy consumption anomalies has increased, and the WBE now detects more problems from

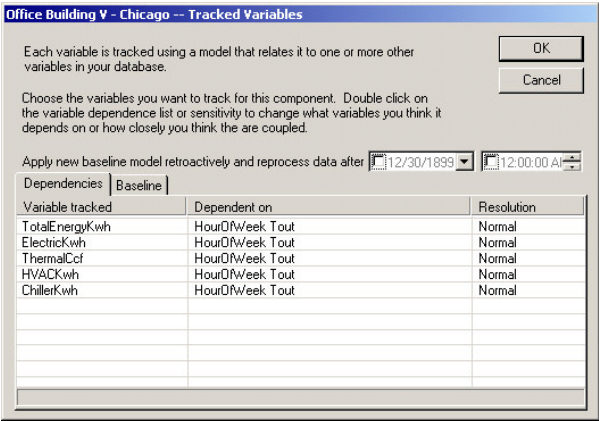
the same data. Click on the center button to return the system to normal sensitivity.

You might wonder why we don't just set the system to the highest sensitivity. The sensitivity is something we recommend be set by the user (Admin) based on experience observing WBD results. Although increasing the sensitivity increases the number of problems detected, it also increases the probability of false alarms, which are not desirable. Each building, its equipment, sensors, and control systems are different; therefore, we recommend developing some experience with the WBD, then re-setting the sensitivity, if needed, based on that experience.

The sensitivity control is not one of the enhanced features added as part of the Energy Commission project, but this is a convenient place to introduce it.

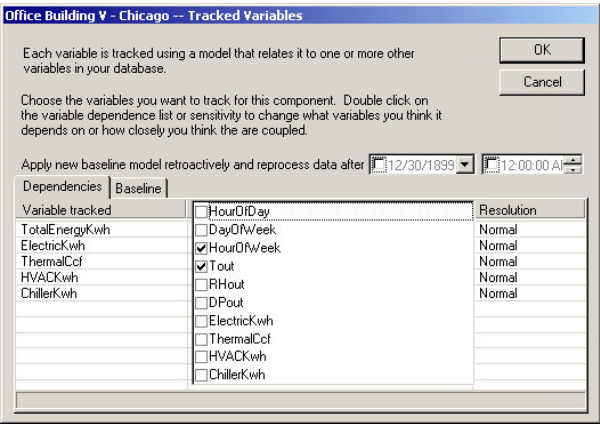


26. Now place your cursor over “WBE Demo” in the configuration tree and click the right mouse button to reveal a drop-down menu. Select “**Tracked variables**” from this menu by clicking the left mouse button on it.



27. The dialog at right will appear. This dialog is used to select the variables to be tracked by the WBE and the independent variables upon which the model of each tracked variable is based (listed in the “Dependent on” column).

28. To explore the ability to select the specific independent variables for a model, double click on the “**Dependent on**” entry for the HVACKwh variable. A list of all possible dependent variables will appear, as shown at right. This list includes all variables currently in the WBE database. If additional variables were included in the database, they would appear in this list. Those variables could include anything for which data could be collected and entered into the database (e.g., hamburgers sold or number of hotel guests registered).



29. Select a variable from the list such as outdoor relative humidity (**RHout**) by clicking on the check box before the variable name. Then click anywhere on the dialog box outside the drop-down variable list. Notice that the new variable has been added to the list of “Dependent on” for HVACKwh. The next time this tracked variable is displayed the system will automatically recalculate the values to display on the graph based on this new model.

Office Building V - Chicago -- Tracked Variables

Each variable is tracked using a model that relates it to one or more other variables in your database.

Choose the variables you want to track for this component. Double click on the variable dependence list or sensitivity to change what variables you think it depends on or how closely you think the are coupled.

Apply new baseline model retroactively and reprocess data after 12/30/1899 12:00:00 AM

Variable tracked	Dependent on	Resolution
TotalEnergyKwh	HourOfDay	Normal
ElectricKwh	DayOfWeek	Normal
ThermalCcf	HourOfWeek	Normal
HVACKwh	Tout	Normal
ChillerKwh	RHout	Normal

Dates for which to apply this new model can be selected from the date and time boxes that appear at the end of the line “Apply new baseline model...” Clicking on the check boxes before the date and time will bring up 12:00 AM on the current date, which will be the date and time for which the new model(s) will apply. If you would like the new model(s) to apply to data already collected, you need only specify the date and time for which you would like the new model(s) to first be used.

30. The specific variables tracked can also be specified by the Admin user subject to some limitations. A maximum of five (5) energy variables may be tracked by the WBE at one time for a single building- level entry in the configuration tree. If five variables are currently tracked, as in the case shown, one or more tracked variables must be deleted before new ones can be added.

Office Building V - Chicago -- Tracked Variables

Each variable is tracked using a model that relates it to one or more other variables in your database.

Choose the variables you want to track for this component. Double click on the variable dependence list or sensitivity to change what variables you think it depends on or how closely you think the are coupled.

Apply new baseline model retroactively and reprocess data after 12/30/1899 12:00:00 AM

Variable tracked	Dependent on	Resolution
TotalEnergyKwh	HourOfDay Tout	Normal
ElectricKwh	DayOfWeek Tout	Normal
ThermalCcf	HourOfWeek Tout	Normal
HVACKwh	Tout	Normal
ChillerKwh	RHout	Normal

To explore this, right click on “**ChillerKwh**.” A drop down menu will appear. Select “**Delete**” from the menu to delete ChillerKwh from the list of tracked variables. Now there are only four tracked variables and a new one can be added.

31. Double click on “(add variable)” listed in the “Variable tracked” column. This will reveal a drop-down list of variables that appear in the WBE database and are not already tracked. Any of the listed variables can be selected to track. Now let’s also delete “HVACKwh” from the list of Variables tracked by right clicking on it and then selecting “Delete.”

Office Building V - Chicago -- Tracked Variables

Each variable is tracked using a model that relates it to one or more other variables in your database.

Choose the variables you want to track for this component. Double click on the variable dependence list or sensitivity to change what variables you think it depends on or how closely you think the are coupled.

Apply new baseline model retroactively and reprocess data after 12/30/1899 12:00:00 AM

Variable tracked	Dependent on	Resolution
TotalEnergyKwh	HourOfWeek Tout	Normal
ElectricKwh	HourOfWeek Tout	Normal
ThermalCcf	HourOfWeek Tout	Normal
HVACKwh	HourOfWeek Tout	Normal
(add variable)		

Tout
RHout
DPout
ChillerKwh

Office Building V - Chicago -- Tracked Variables

Each variable is tracked using a model that relates it to one or more other variables in your database.

Choose the variables you want to track for this component. Double click on the variable dependence list or sensitivity to change what variables you think it depends on or how closely you think the are coupled.

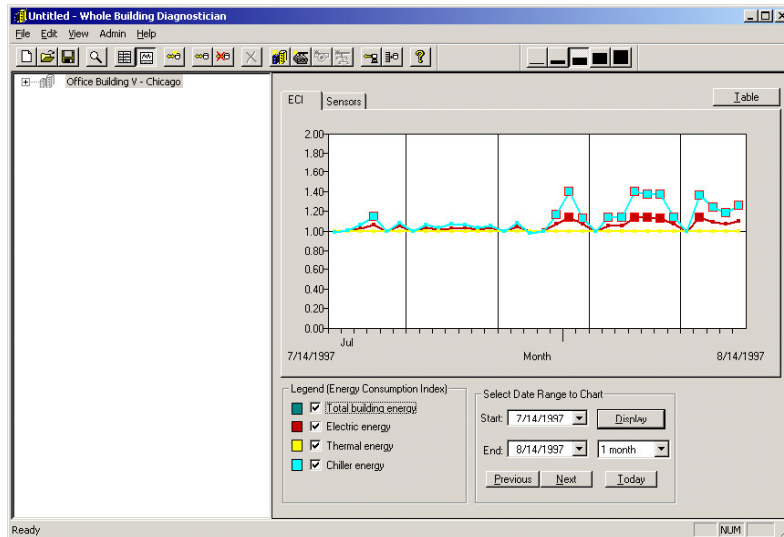
Apply new baseline model retroactively and reprocess data after 12/30/1899 12:00:00 AM

Variable tracked	Dependent on	Resolution
TotalEnergyKwh	HourOfWeek Tout	Normal
ElectricKwh	HourOfWeek Tout	Normal
ThermalCcf	HourOfWeek Tout	Normal
ChillerKwh	HourOfWeek Tout	Normal
(add variable)		

Add ChillerKwh back on the row where HVACKwh was listed before we deleted it. Accomplish this by double clicking on the first “(add variable),” selecting “ChillerKwh” from the drop-down menu, and then clicking elsewhere on the dialog box. This will add ChillerKwh to the list of Variables tracked. Notice though that no “dependent on” variables are yet selected for the ChillerKwh model. To select variables for the model, double

click on the space in the ChillerKwh row under the “Dependent on” column to reveal the variables available, and then follow the same procedure used in step 29 above to add variables to the model.

In order for the change to affect the current diagnostic display, change the date to “Apply new baseline model ...” to July 1, 1997. To do this click on the check box before the date. Then click on the down arrow immediately following the date. A calendar will appear. Use the back arrow to navigate to July 1997. Then click on July 1.

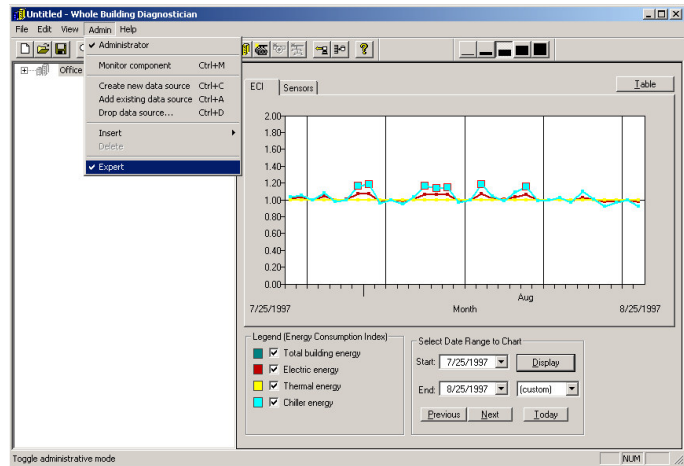


Click “**OK**” to return to the main WBE display. Notice in the Legend that “Chiller energy” has been added in place of “HVAC energy” and only four tracked variables now appear. If this change does not display, click on the **Display** button. This will refresh the display, and the change will appear. Note that the display refreshes automatically once per minute. If you wait until the next automatic refresh, the

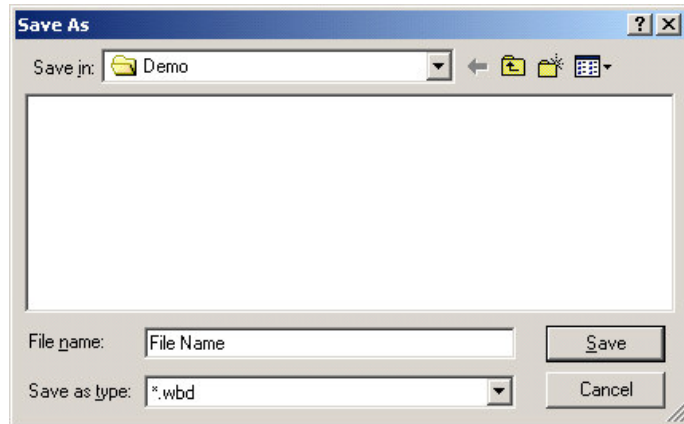
interface will change the display without you pushing the **Display** button.

Closing the WBD

32. When you are done exploring these features, click on **“Admin”** on the menu bar. Then click on **“Expert”** in the drop-down menu to move out of Expert mode, as a precaution to prevent accidentally damaging the WBD database.



33. You may now close the WBD simply by clicking **“File”** on the menu bar and selecting **“Exit”** from the drop-down menu. A dialog box will then appear asking whether you would like to “Save Changes to Untitled?” If you would like to delete your WBD configuration, simply click **“No,”** and the WBD will close. If you would like to save your current WBD configuration, click **“Yes”** (note the .wbd file extension). The “Save As” dialog box at right will appear. Type your selected file name in the white space after “File name:” and click **“Save.”** The file will be saved for future use, and the WBD will close.



Energy Efficient and Affordable Small Commercial and Residential Buildings Research Program

a Public Interest Energy Research Program

sponsored by the California Energy Commission and the U.S. Department of Energy Office of Building Systems, State and Community Programs

Instructions for Configuration of the Whole-Building Diagnostician Software Release 2.10-162

Project 2.6 – Enhancement of the Whole-Building Diagnostician

Task 2.6.3 – WBE Configuration Instructions

Nathan N. Bauman
Teresa A. Carlon

August 2003

Prepared for
Architectural Energy Corporation

Battelle Northwest Division
Richland, Washington 99352

THIS REPORT WAS PREPARED AS A RESULT OF WORK SPONSORED BY THE CALIFORNIA ENERGY COMMISSION (COMMISSION). IT DOES NOT NECESSARILY REPRESENT THE VIEWS OF THE COMMISSION, ITS EMPLOYEES, OR THE STATE OF CALIFORNIA. THE COMMISSION, THE STATE OF CALIFORNIA, ITS EMPLOYEES, CONTRACTORS, AND SUBCONTRACTORS MAKE NO WARRANTY, EXPRESS OR IMPLIED, AND ASSUME NO LEGAL LIABILITY FOR THE INFORMATION IN THIS REPORT; NOR DOES ANY PARTY REPRESENT THAT THE USE OF THIS INFORMATION WILL NOT INFRINGE UPON PRIVATELY OWNED RIGHTS. THIS REPORT HAS NOT BEEN APPROVED OR DISAPPROVED BY THE COMMISSION NOR HAS THE COMMISSION PASSED UPON THE ACCURACY OR ADEQUACY OF THE INFORMATION IN THIS REPORT.

Configuration of the Whole-Building Diagnostician Software

This document describes how to set up the Whole-Building Energy (WBE) module of the Whole-Building Diagnostician (WBD) for use in monitoring whole-building and major end-use energy consumption. It is a companion to the *Instructions for Installation of the Whole-Building Diagnostician Software Release 2.10-162*. Users should install the Whole-Building Diagnostician (WBD) and become familiar with it by using demonstration databases and following the instructions for installation before proceeding to this document. This document describes how to set up the WBE software to collect new data or process data in existing data bases.

Configuration Instructions for the Whole-Building Diagnostician (WBD) Software Release 2.10-162

Before starting to use the WBD, you should plan the number of databases you will use in the configuration of the WBD. Presently, we recommend one database per diagnosed system [i.e., one database for each OAE set up for an air handling unit (AHU) and one database for each WBE module set up for a building or facility]. This recommendation is intended to help minimize the access and processing times; it is not an absolute constraint. Note, however, that each database must have at least one building in it, so that when our recommendation is followed, each AHU appears under its own building (and, as a result, a building will generally appear multiple times in the directory tree).

The user should also note the distinction between the WBD configuration file (*.wbd) and the database files (*.mdb). The *.wbd configuration file contains the tree structure to be displayed, literally the list of databases whose building and system configurations are displayed. The components of a single building may be contained in any arbitrary number of databases (*.mdb). The database files contain the tree structure (as well as other data) for the systems contained in that database, which must include one or more buildings and all or some subset of the systems in them. Other systems for the building may appear in separate databases, but then the building will appear more than once in the tree structure (once for each database containing some of the building's systems).

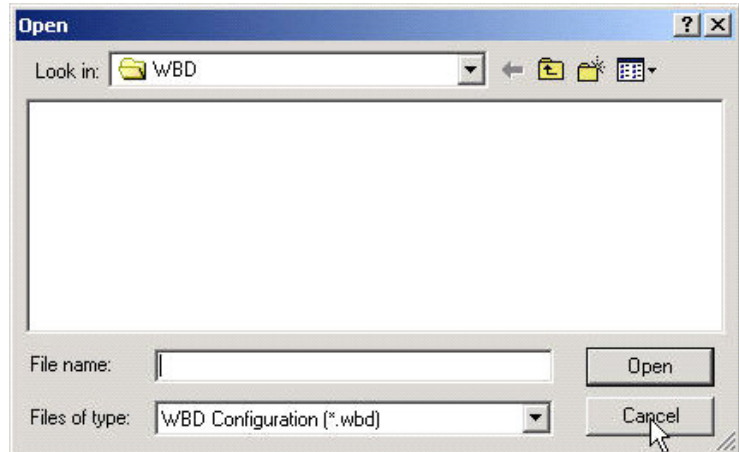
Configuring the WBE

1. Start the WBD by double clicking on the Whole-Building Diagnostician icon on the desktop.

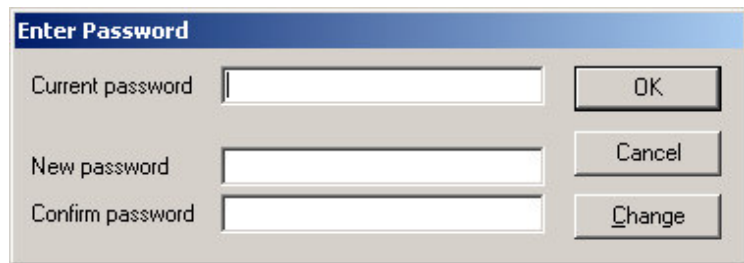


Whole-Building
Diagnostician

2. A window will appear defaulting to the WBD directory. Click **Cancel** to create a new (untitled) configuration. Note: If configuration files exist already you may select one now. The steps that follow assume you are creating a new configuration (i.e., not selecting an existing configuration).

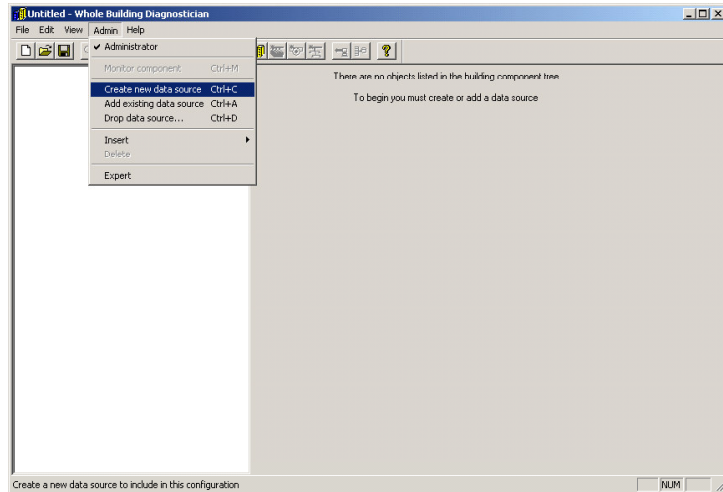


3. The WBD must be in Administrator mode to continue with configuration. You can check this by clicking on **Admin** on the menu bar. A drop-down menu will appear. The "**Administrator**" item in the menu should have a check mark before it. If it does, proceed to step 4.

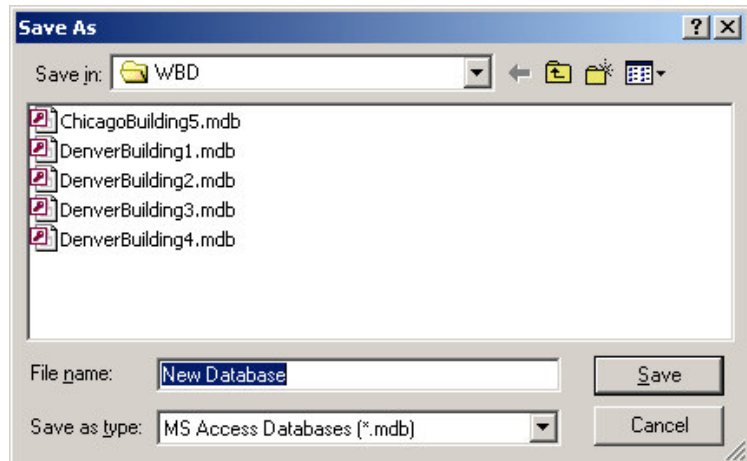


If there is no check mark before "**Administrator**" on the menu bar, click on "**Administrator.**" The dialog box at right above will appear, and you will need to enter a password to re-enable the administrator setting. If an administrator password has already been set, enter it in the "Current password" box and click on **OK**. If a password has not yet been set, you can enter the default password, *wbdadmin*, click **OK**, and then proceed to step 4. If a password has not yet been set and you are the administrator for the site, you can enter your desired password in the box labeled "New password," re-enter it in the "Confirm password" box, and then click on the **Change** button. Then enter your new password into the "Current password" box and click on **OK**. Be sure to select a password consistent with good password practices and remember your password for future use of the WBD as an administrator. Proceed to step 4.

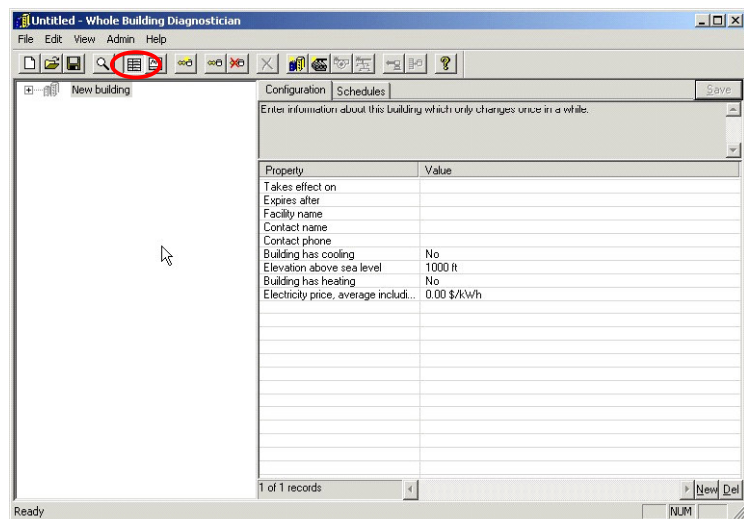
4. On the menu bar, select **Admin** and click on **Create a new data source**.



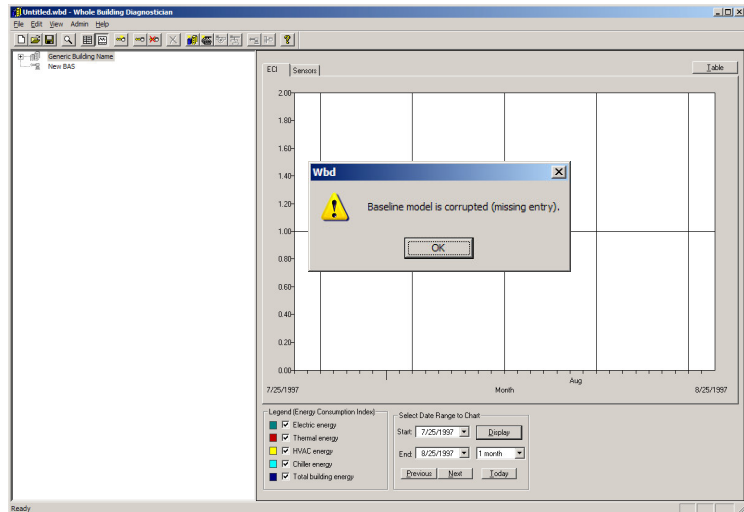
5. A "Save As" window will open for the WBD directory. Type the filename of your database in the box indicated. Example names include the building name, an abbreviation for the building, or an abbreviation for a grouping of buildings (e.g., a campus). Once you have input the name click **Save**.



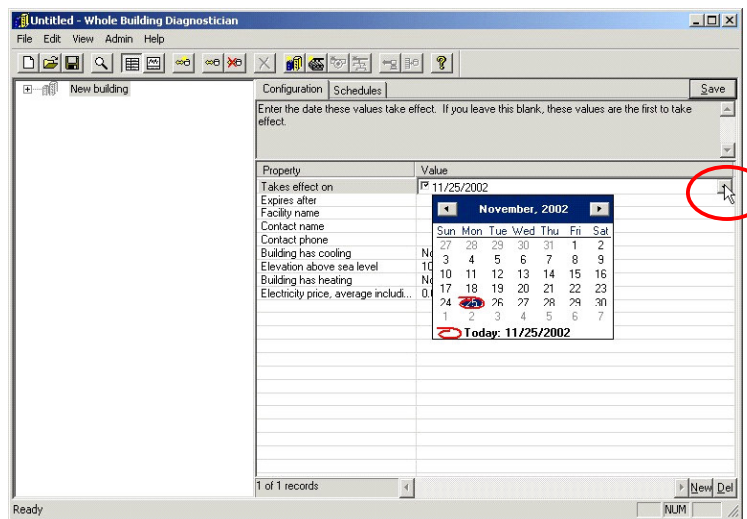
6. The window at right should appear once the database is created. If instead the second window (below right) or one like it with the WBD warning dialog box on it appears, click on the OK button in the dialog box as many times as necessary for it to disappear (may take 3 or 4 clicks). When the dialog box has disappeared, click on the "new component description" icon circled in red at right. This will display the first window (top right).



The left pane of the window is where the “tree” structure appears. The tree lists all buildings and components that are a part of this configuration. Similar to Windows® Explorer, a “+” sign next to an object indicates that there are other subcomponents below and part of that object. By default, the *New building* displayed in the tree has a plant, an air-handling unit, and a zone as its components (which will be discussed in subsequent steps). The right-hand pane of the window shows the “Configuration” and “Schedules” tabs for the *New building*. Some of the properties have default values already entered. Later, you will review this list of properties and make the necessary changes to values for your configuration.



7. Today's date with a blank check box before it should appear as the value for the **Takes effect on** property. If no date is shown, double click on the space where it should be and it will appear. Then click on the check box before today's date to select it as the date on which this configuration will take effect.

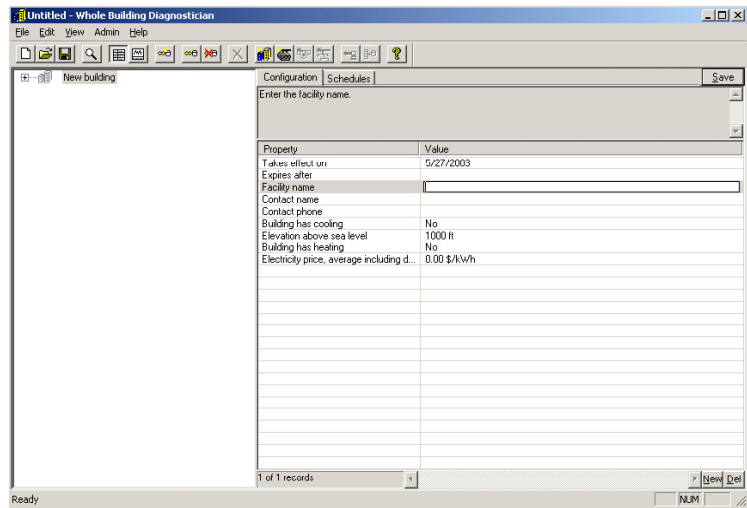


To select a different date, click the down arrow on the vertical scroll bar (shown in the red circle at right). A calendar box will appear. Use the left and right arrows on the calendar, respectively, to navigate backward and forward through the months. To select a specific date on the calendar as the date on which this software configuration will take effect, click on the date. The calendar will close and the chosen date will be shown with a check mark in the box preceding it.

8. The second Property listed is the *Expires after* date. We recommend that this date be left blank now because it is usually not known at the time a configuration is created. Sometime in the future there may be modifications to the building or its configuration, and it may be necessary to create a new configuration. At that time, the date for this configuration to expire (value of the *Expires after* date) can be entered and a new configuration created.

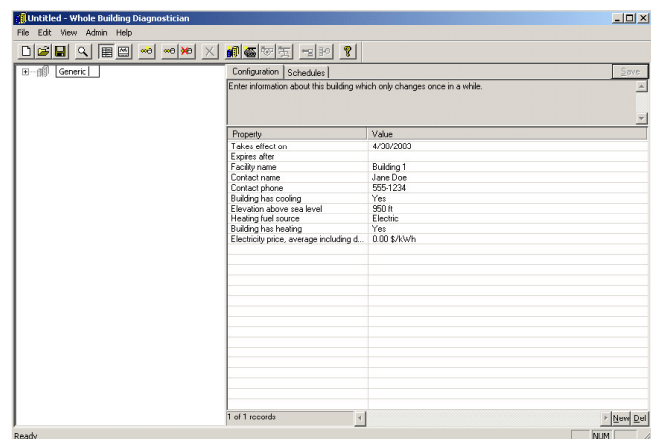
Tip: A double mouse click on any value cell will open the selection box for that property.

9. Double click on the property cell for **Facility name** and enter an appropriate building name in the Value column. Pressing the enter key after entering a name accepts the input value and moves the cursor to the next field. Repeat this process for both the **Contact name** and **Contact phone** for this building. For the next property, **Building has cooling**, select whether the building has cooling or not. The default value is No, indicating that the building does not have cooling. If the building has cooling, select Yes from the drop down menu. Enter the value for **Elevation above sea level** in feet for the building location. By default, the value for the next property, **Building has heating**, is no. If the building has heating, select “Yes” from the drop down list. The final property is the **Electricity price, average including demand** (i.e., a blended rate per kWh accounting for both the amount of electricity used (kWh) and the demand charge, if any). Enter the appropriate amount in \$/kWh in this cell. The building configuration values are now complete.



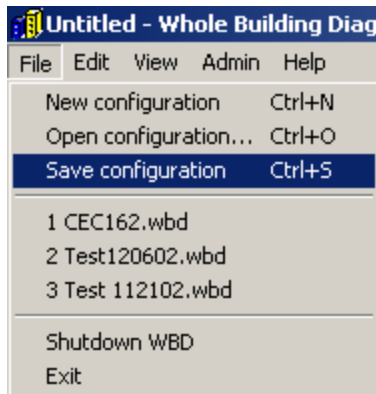
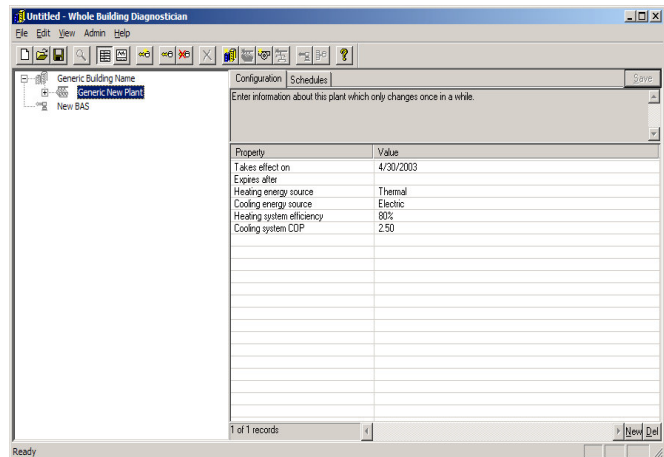
Property	Value
Takes effect on	5/27/2003
Expires after	
Facility name	
Contact name	
Contact phone	
Building has cooling	No
Elevation above sea level	1000 ft
Building has heating	No
Electricity price, average including d...	0.00 \$/kWh

10. Rename the building on the tree by first clicking the left mouse button once on **New building** in the tree to highlight it. Then click the left mouse button again to enable editing of the name. Enter the name you prefer for this building. Then click anywhere outside the edit box to complete assignment of this name.



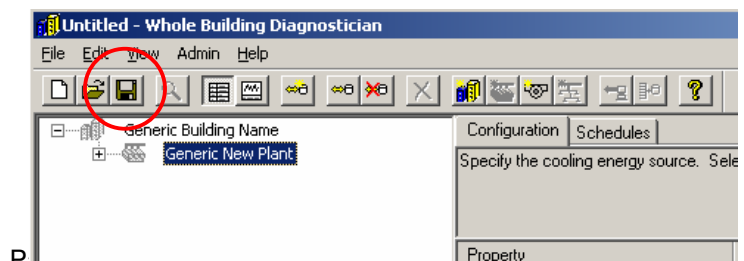
Property	Value
Takes effect on	4/20/2003
Expires after	
Facility name	Building 1
Contact name	Jane Doe
Contact phone	555-1234
Building has cooling	Yes
Elevation above sea level	950 ft
Heating fuel source	Electric
Building has heating	Yes
Electricity price, average including d...	0.00 \$/kWh

11. Click the “+” sign to the left of the building name to expand the next component level, **New Plant**. Rename the *New Plant* using the same process as in step 10. The window on the right side of the screen displays the configuration properties for the *New Plant*. Some of the values have default entries. Enter the appropriate value for each property. Clicking enter selects the highlighted value from the list and moves the cursor to the next property. **Takes effect on** should be the same date entered at the building level. Leave the **Expires after** field blank. If the value for any property is not known, leave the default value until the correct information can be obtained and entered into the value column.

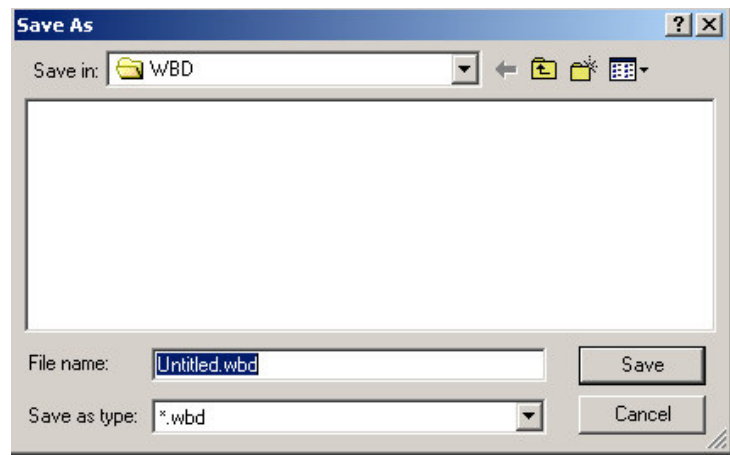


12. Now save the WBD configuration by clicking **File, Save configuration**.

Tip: Clicking on the “disk” icon on the toolbar also will start the save process and bring up the dialog box in the following step.



13. Type the filename for your configuration and click **Save**.

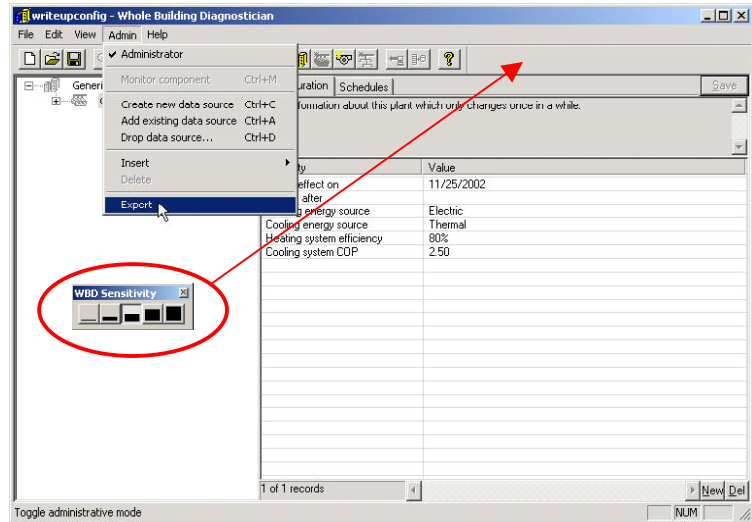


Configuring for the Source of Data

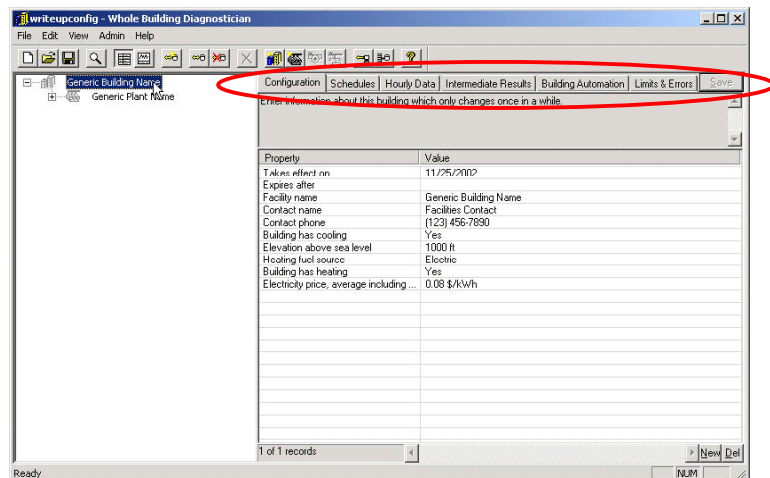
The following steps will add the network component and set up the data collection for the WBE module.

14. Using the toolbar, enter the *Expert* mode by selecting **Admin** and then clicking on **Expert**. When asked to confirm switching to *Expert* mode, click **Yes**. A *WBD Sensitivity* box will appear on your screen. Simply click and drag the box to your toolbar or click the "x" to close the box. The sensitivity setting will not be modified.

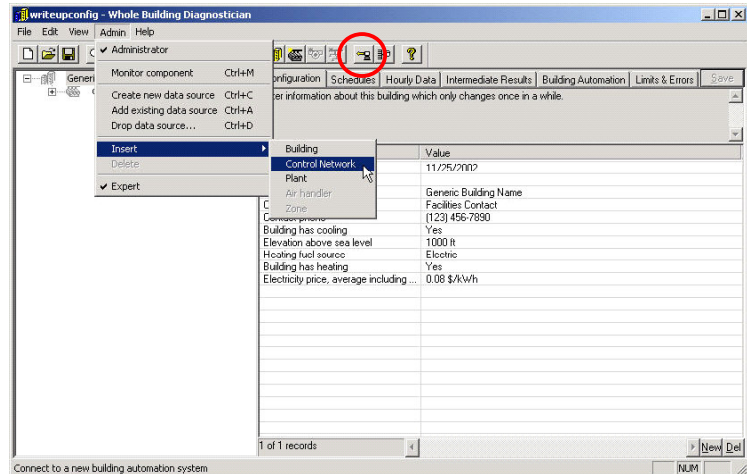
Caution! When in *Expert* mode, it is possible to cause irreparable damage to the database, therefore, the user should be careful not to change any parameters unless otherwise advised in this document.



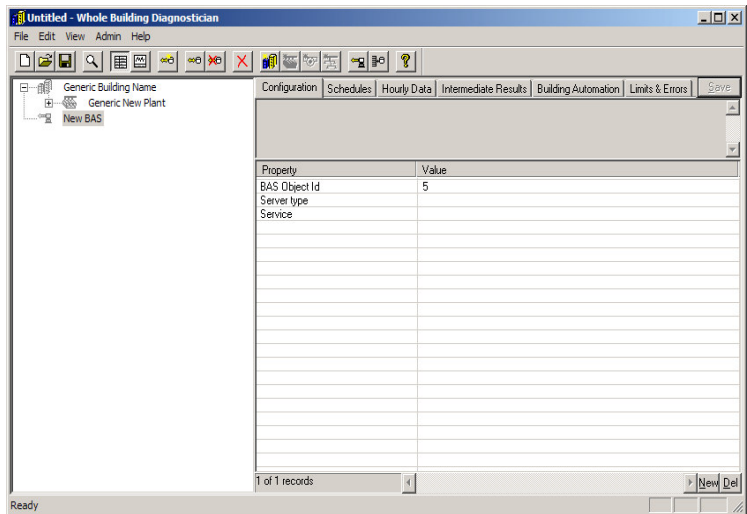
15. Refresh the screen by clicking once on another object on the tree. The circle in the diagram at right identifies tabs that will now appear across the top of the right-hand pane of the window, four of which are new: *Hourly Data*, *Intermediate Results*, *Building Automation*, and *Limits & Errors*.



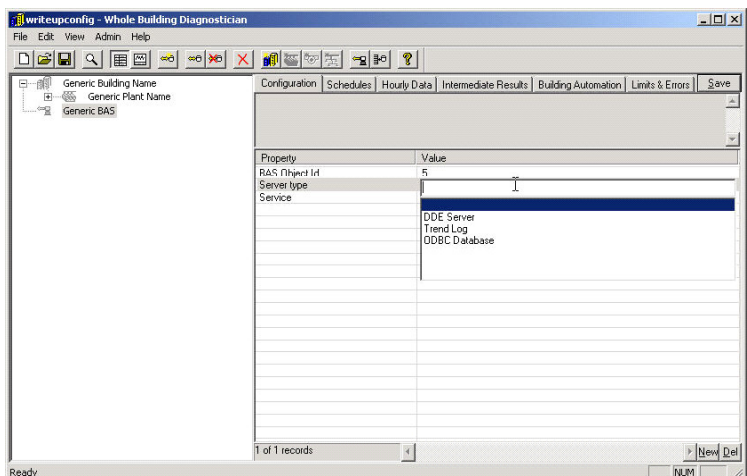
16. We will now add a network from which data will be gathered. There are two ways to add a *Network*, either from the menu bar by selecting **Admin, Insert, Control Network** or by selecting the **Connect to BAS** icon identified by the red circle in the diagram on the right.



The window at right will be displayed. A New BAS object will appear in the tree and the Configuration view for this object (network component) will appear in the right pane. Only the BAS Object Id property will have a value assigned. This value is automatically determined by the software and should not be modified.



17. Double click on the value cell for the **Server type**. A drop down selection box will appear. Select the BAS server type that will be used. Select **DDE Server** if the data will come through a BAS DDE Link, select **Trend Log** if the data will come from a file, and select **ODBC Database** if the data will come from an ODBC database.



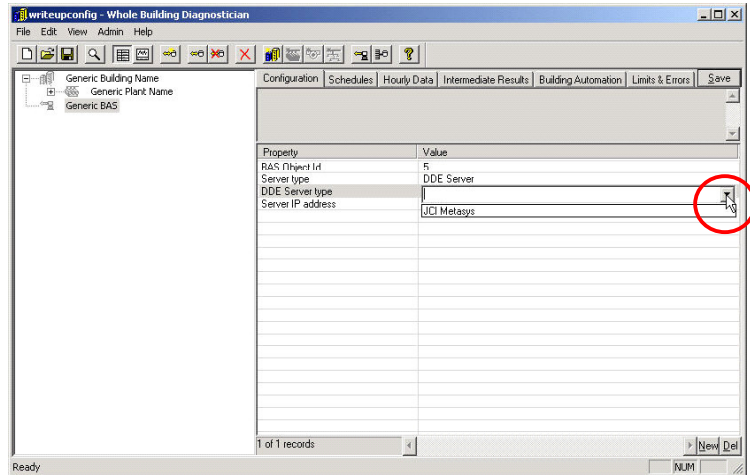
The next several steps depend on the type of server you have selected. If you are using a *DDE Server*, follow steps 18 through 20. If you are using a *Trend Log* server, see steps 21

through 23, and for an *ODBC* server, see steps 24 through 26. Note that some of the properties on the configuration screen change depending on the specific server type, so selection of the correct server is crucial. The software automatically modifies the input requirements depending on the selections that you make.

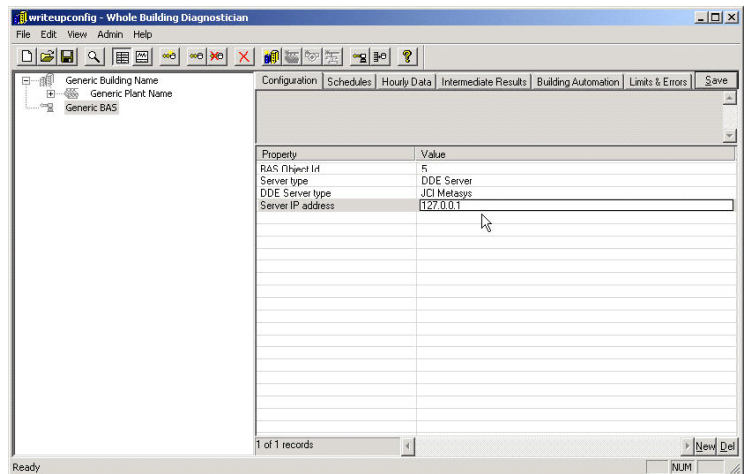
DDE Server

18. Double click in the value cell for the ***DDE Server type***.

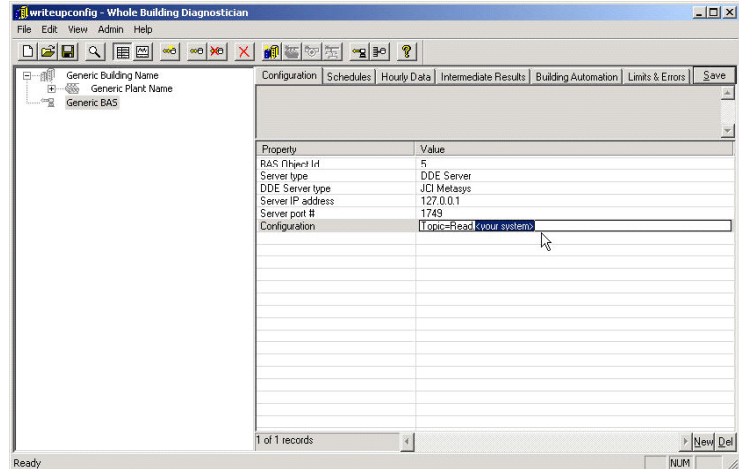
Click on the down arrow on the far right-hand side of the box to see the selectable entry, ***JCI Metasys***. If *JCI Metasys* is not your DDE Server type then a special driver will be required for the WBD to properly acquire your BAS data. There are a few drivers currently available for non-JCI DDE servers; please check with the PNNL representative for options concerning your system. For now we will assume that you are using JCI Metasys.



19. Double click the value cell for the ***Server IP address***. Enter the IP address that the DDE server resides on. If the DDE server resides on the same machine the WBD runs on, enter **127.0.0.1**. This IP address tells the WBD that it does not need to go over a network to connect to the server, but will find it on this machine. The ***Server port #*** will be automatically filled in—do not change this value!

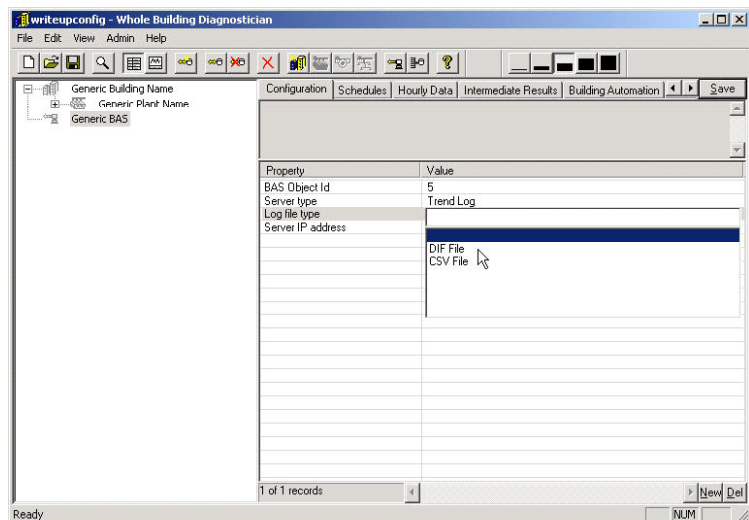


20. Double click on the **value** cell for the Configuration. Replace <your system> with the path for your building automation system. You may need to consult your controls specialist or contractor for this information. After entering the path, save the configuration file by clicking on **File** in the menu bar and **Save configuration** in the drop down menu. Then skip to step 27.



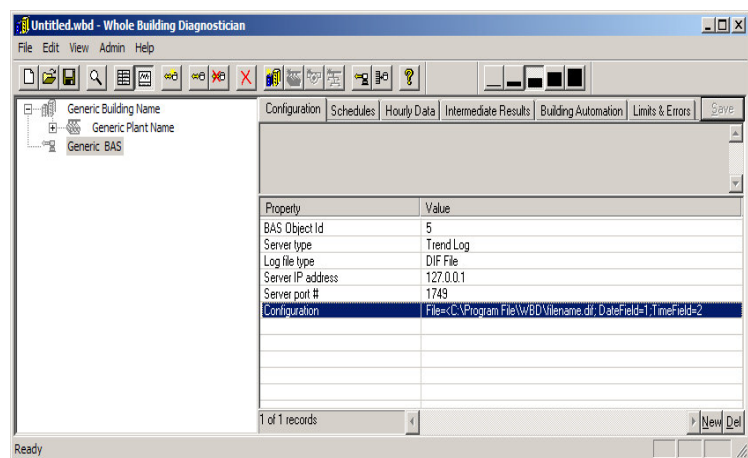
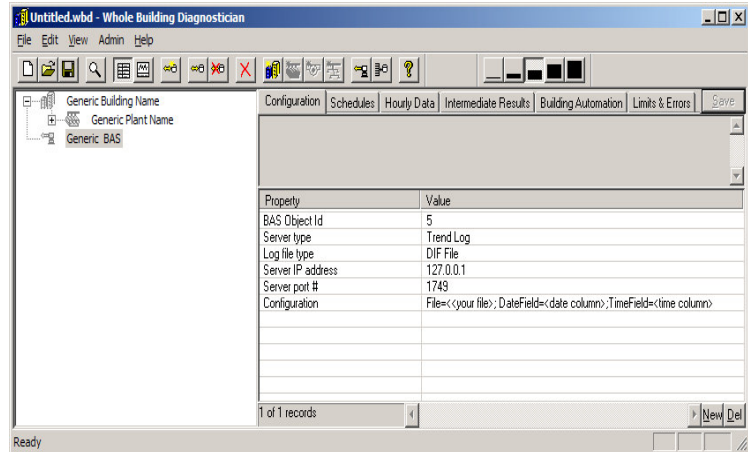
Trend Logs

21. Continue the BAS configuration set up using a **Trend Log** server type. Double click on the cell for **Log file type**. A drop down selection box will appear with two file types that can currently be read by the WBD—**DIF File** (tab delimited file) or **CSV File** (comma separated variable). Select the type that you will use. Note that Excel can save your systems text file as either of these types if your system cannot save to this format directly.



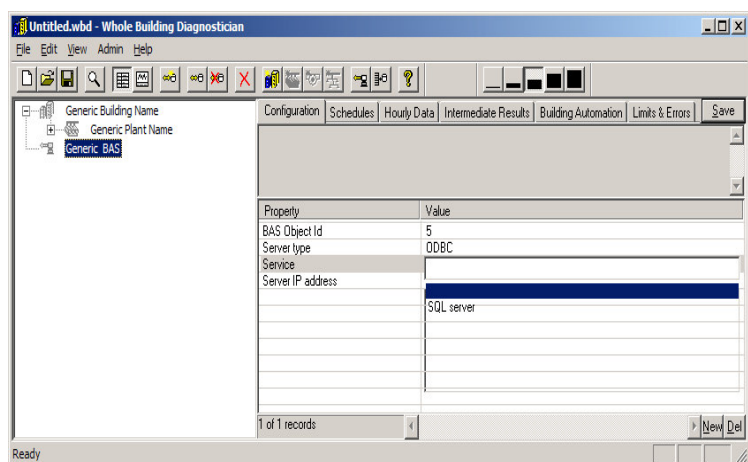
22. Double click the value cell for the **Server IP address** and input the IP address for the computer that will have the trend log file. If the trend log resides on the same machine as the WBD, input the IP address 127.0.0.1. The **Server port #** value will be filled in automatically—do not alter this entry!

23. Double click to select the **Configuration** cell and then replace <your file> with the complete path to the trend log file. Note that the file needs to have a date and a time stamp associated with the data. To assign these, replace <date column> in the figure with the date field column number and <time column> with the time field column number, inserting the appropriate column numbers where the date and time are stored in the trend log. An example with a path entered is shown in the bottom right figure. After entering this complete path name, save the WBD configuration file and skip to step 27.



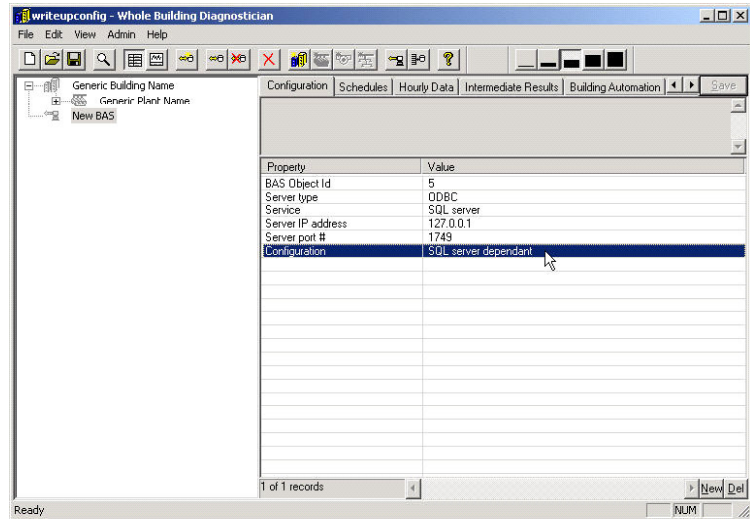
ODBC Database Server

24. Continue the BAS configuration set up using an *ODBC* server type. Double click on the value cell for **Service**. A drop down box will appear with a single available selection, **SQL server**. Select this as the service. Currently this is the only server supported by the WBE for ODBC server types.



25. Double click the value cell for the **Server IP address** and input the IP address for the computer that will have the ODBC file. If the ODBC file resides on the same computer as the WBD, input the IP address 127.0.0.1. The **Server port #** value will be filled in automatically—do not alter this entry!

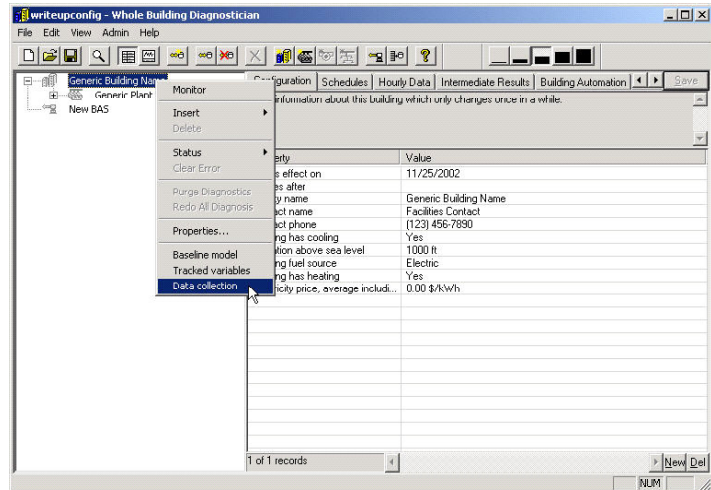
26. The final value, which is for the **Configuration**, is server dependant. On your screen it will appear blank; however, we display text in the figure at right to indicate that you will need to contact your SQL server administrator to obtain this value. After entering the value, continue with step 27.



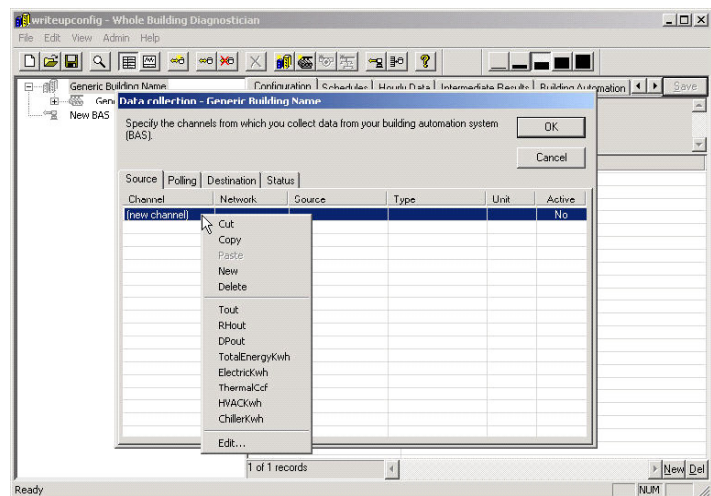
Configure Channels for Data Collection Using the WBD Interface

Now that the building, plant, and network components have been configured, you can set up the data collection for the *Whole Building Energy* module.

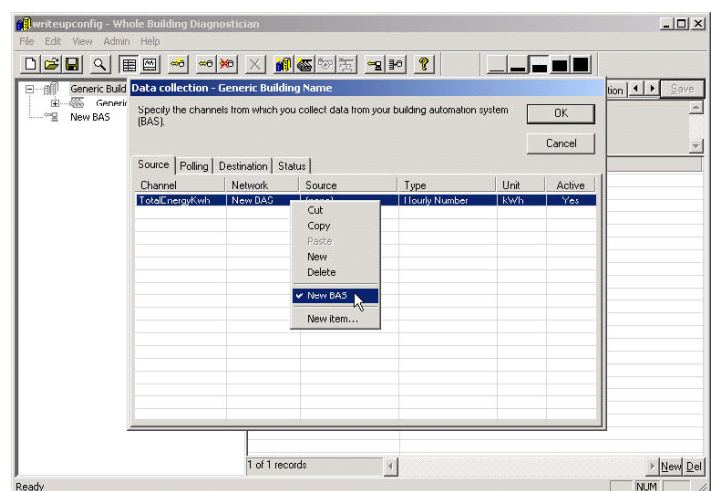
27. In the tree structure, right click on the building name. A drop down menu will appear. Click on **Data collection**. A BASLink “no records matched” warning box will pop up. Click “OK.”



28. A *Data collection* window will appear for your building. Right click on the first cell under **Channel**, which has the text “(new channel)” in it. From the selection box, choose the channel you would like to set up data collection for. This is a ordinarily an energy use you wish to track. For this example, we start with *TotalEnergyKwh*.

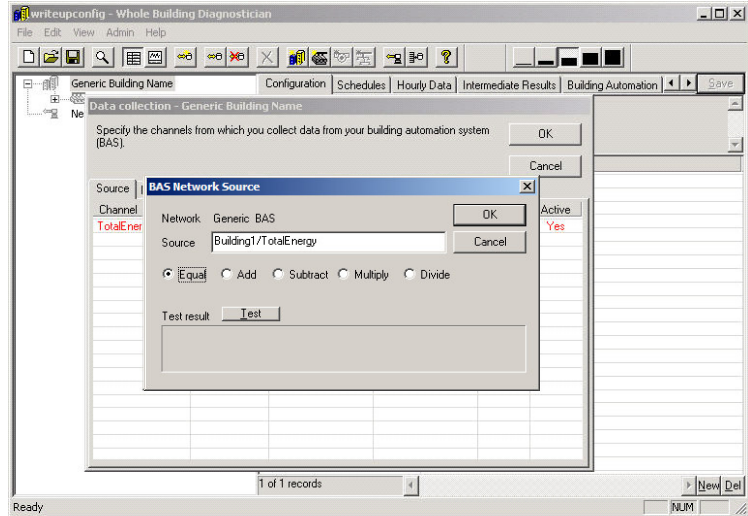


29. The remaining cells in the row populate with their default information. Right click on the **Network** cell and select the **New BAS** for this channel. Note that if you set up your configurations with multiple buildings and separate databases for each building, you will have multiple BAS networks in this list to choose from. Appropriate meaningful naming of these will



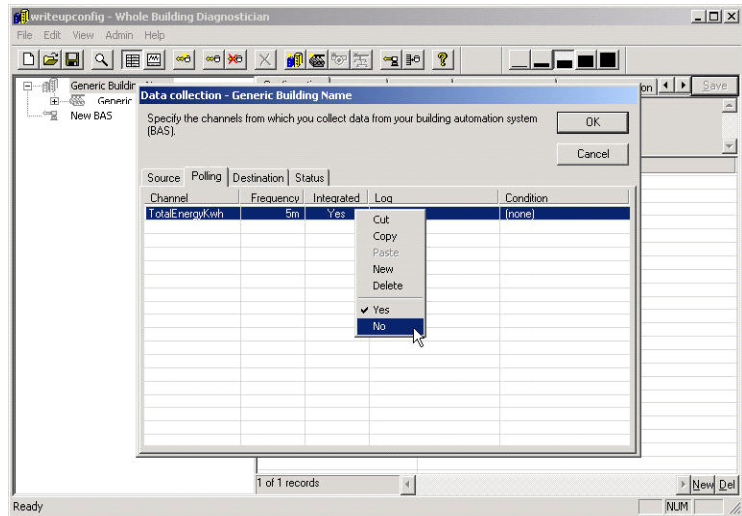
aid in setting up data collection.

30. Right click on the **Source** cell and select **Edit**. A **BAS Network Source** dialog box will appear. Input the source identifier applicable to your data collection method in the white box after "Source". If you are using Metasys DDE, input the path to the specific BAS point. For *Trend Log* data, input the database column number for that data point (e.g., 3), and for *ODBC* data, input the ODBC specific identifier (see your database administrator, if you are unsure of this information). An example path for a Metasys DDE server is shown in the figure. The radio buttons allow sequential operations to be performed on that data point; however, for now we are only setting up straight data collection, so choose the *Equal* radio button, then click **OK**.

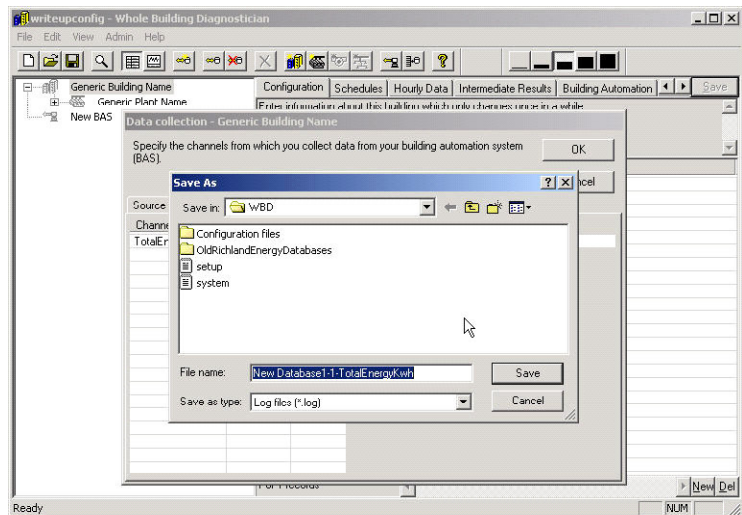


31. The *Type*, *Unit*, and *Active* cells will all have the default values associated with your selected channel automatically entered. All of the channel defaults that appear in the drop down selection box have these associated values. If you are creating a new channel that is not on the list, then you may need to modify the *Type* and *Unit* values. Right clicking on the cell for each of these provides you with the available options.
32. Select the *Polling* tab near the top of the *Data collection* window. The default values are set to collect the data at a frequency of 5 minutes (5m in the menu) and to integrate the values over the hour. Although we recommend a 5-minute frequency for data collection, this value can be modified provided that the frequency is no greater than 60 minutes. To modify the frequency, right click on the *Frequency* cell and select the value best suited for your needs.

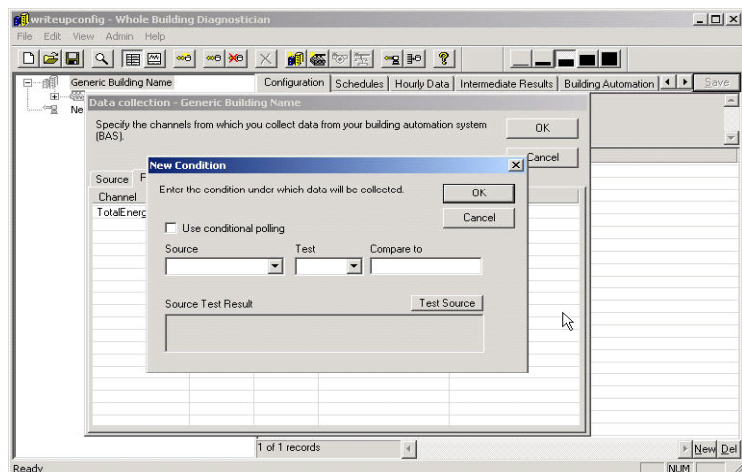
33. To modify the *Integration* of the data, right click on the cell, then select no (or yes).
NOTE: If you decide not to integrate the values, then you will be collecting instantaneous values—the WBE will assign the last instantaneous value collected during an hour to each hour. So, for a 5-minute data collection frequency, the WBD will assign the value collected at 1:55 p.m. to the time of 1:00 p.m.



34. To log data for any point (which can be used to complement “live” data collection), right click on the **Log** cell and select **Browse**. A **Save As** window will appear where you can name the file (this file name currently defaults to the database name “New Database1-1-
 <Channel>”, with <Channel> replaced with the name of the specific channel associated with the row on which you right clicked). Enter the file name you prefer and then select the location in the “Save in:” box to which you want the file saved on your hard drive (currently defaults to the WBD folder). After naming the file and selecting a location for storage, click **Save**.



35. To set up collection of data that is conditional on a relationship between data points or a data point and a benchmark, right click on the **Condition** cell, and select **New item**. A **New Condition** window pops up. Click on the check box to “Use conditional polling.” A check mark should appear in the box. Enter the



Source (the data point you want to evaluate in the condition) in the box provided, select the Test (a Boolean operation) that will be used to compare the source value, and then enter the “Compare to” data point (which must already be set up in data collection) or a constant. When finished, click **OK**. Note that ordinarily this feature is not used for data collection associated with the WBE module.

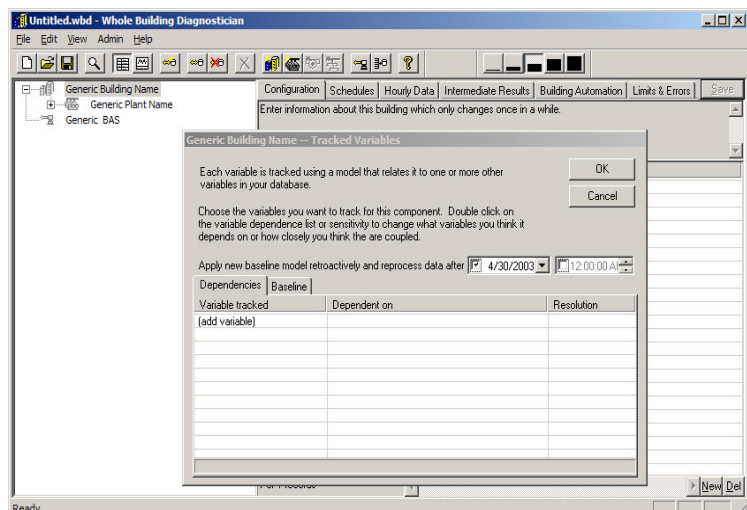
36. Now select the **Destination** tab in the Data collection window. This displays the units in which the data points are stored, their reliabilities, errors, and low- and high-limit values. Although most of the channels available in the selection box have defaults available, any new channels (tracked variables) and some of the pre-existing channels may need these values input by the user.

Reliabilities represent the certainty to which you estimate the value of a data point is known (e.g., we recommend a value of 95% for electricity consumption). The error represents the estimated tolerance of the sensor used to measure the variable in the units of measurement (e.g., we generally use 1 kWh for electricity consumption, representing plus or minus 1 kWh). The values for the low- and high-limits are used to establish reasonable ranges for measured variables. Values below the low limit or above the high limit are flagged by the WBE in a pre-screening process as so unreasonably high or low that the data should not be used. These limits should be selected to define a sufficiently wide range between them that no physically reasonable values are flagged. For example, for outdoor-air temperature, values of -40°F and 170°F might be designated for the low and high limits, respectively. **Note: when modifying the High limit value of a channel, the input value will be a multiple of the unit that is associated with that channel (e.g., if the unit is kWh, then a value of 100 would produce a High limit of 100 kWh).**

37. The data collection setup for the first single channel is now complete. To add a new channel, click on the **Source** tab, right click on the current channel, and select **New** from the drop down box. Then repeat steps 28 through 36 for all of the channels that you would like to set up for data collection. After you have added all of the channels of interest, click **OK**.

Baseline Model Setup

38. The WBE uses empirical (baseline) models to provide expected values for tracked variables. To set up a baseline model, right click on the building name in the WBE tree and select **Baseline model**. A **Tracked Variables** box for the selected building will open. A typical setup will track all of the major energy uses by source (e.g., total

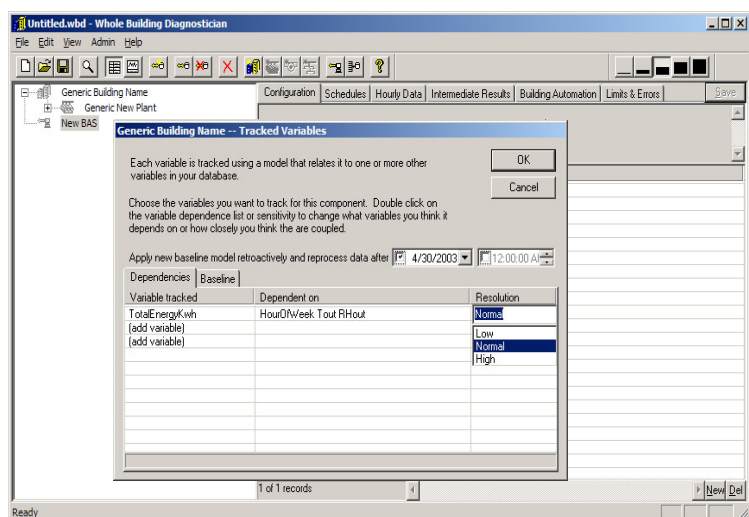
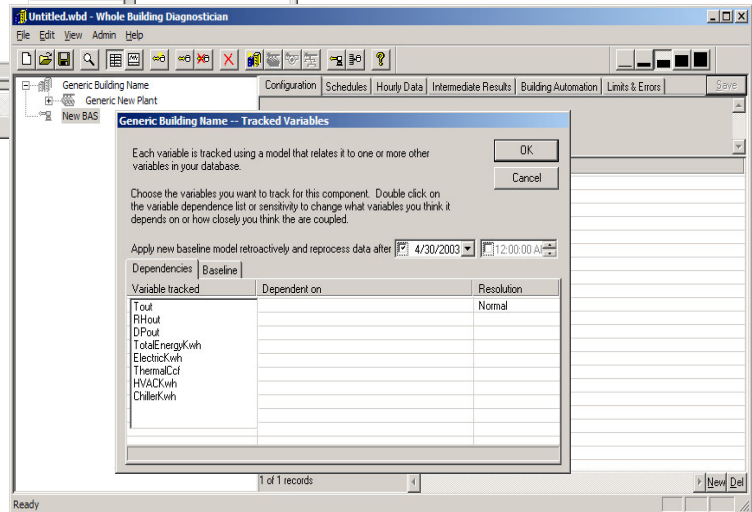
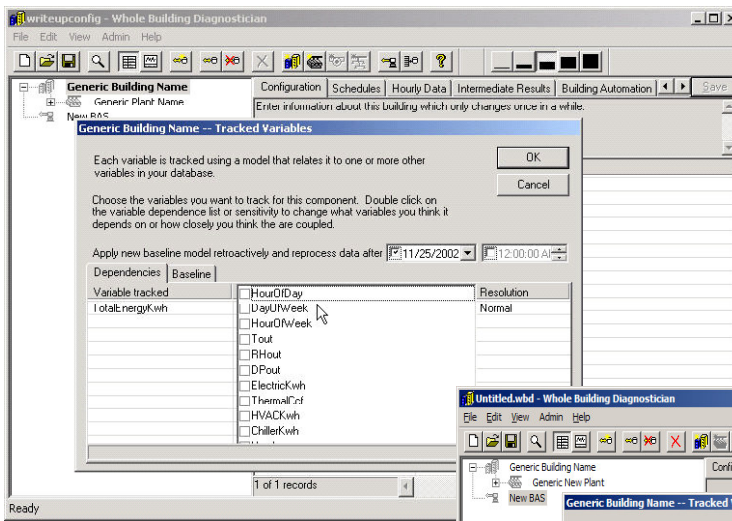


electricity,

chiller electricity, gas, etc.) and make them dependent on weather variables (typically outdoor-air temperature and humidity) and schedule. Other variables can be used (such as number of hotel guests or number of hamburgers sold); however, only those variables set up for data collection are available for use by the models.

39. Double click on the **Variable tracked** cell with the entry “(add variable).” A drop down selection box will appear with all variables in the database shown. Select the data point that you want to track in the model and double click on it. The **Dependent on** selection box will open. Select the variables that you want the tracked variable to depend on in the model. Typically these are HourOfWeek, Tout (outdoor-air temperature), and RHout (outdoor relative humidity) for tracked variables that are driven primarily by schedules and weather. If relative humidity data are not being collected, we recommend using outdoor-air temperature along with a time variable.

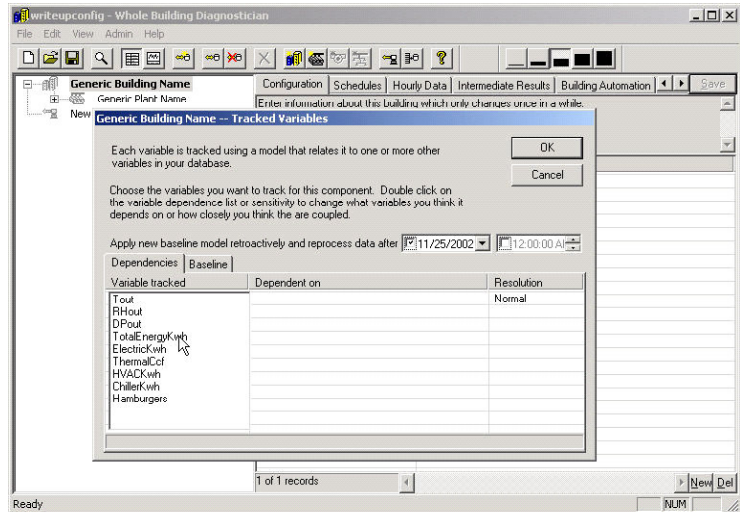
After making your selections, click on the first cell under **Resolution**. Resolution determines the sensitivity of the resulting diagnostics. Low sensitivity requires larger differences from the baseline before an “alarm” is triggered for a tracked point, and High sensitivity uses small differences to trigger an alarm. In most cases, a Normal



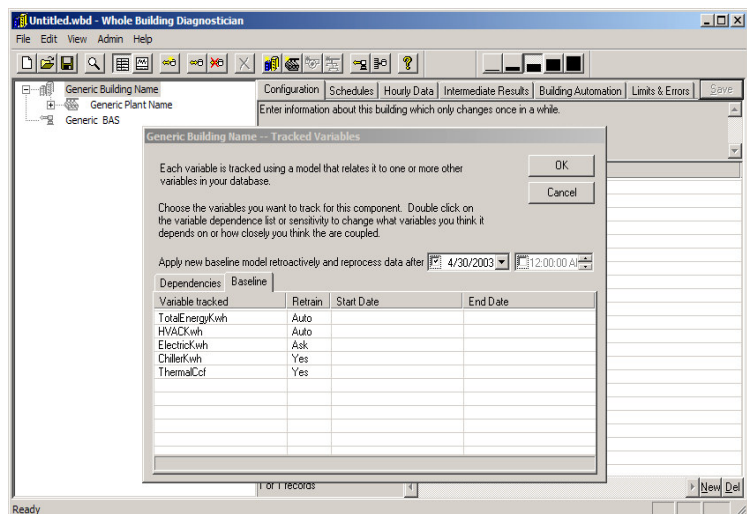
setting is sufficient. Note that there is a tradeoff between increased sensitivity for triggering alarms and the probability of false alarms—low sensitivity produces fewer false alarms but at the risk of missing a problem condition, while high sensitivity is better at detecting problems but will also provide more false alarms. New users should select a Normal setting initially and then adjust the sensitivity after developing experience with the WBE.

40. Repeat step 39 to add each additional tracked variable. There is a limit of five tracked variables per building entry in the directory tree. In addition, only those variables set up for data collection can be tracked.

Caution! If you single click instead of double clicking on a variable in the “Variable tracked” drop down box, you will lose the ability to add more variables and may lose all previously selected variables to track. Be sure to double click when selecting variables to track. If you mistakenly single click, try again by double clicking. If this works, continue the process. If it does not, you can still recover but must re-select all previously selected variables to track. To recover, right click on the last variable in your list and select **Delete**. The (add variable) option will then show back up. Then perform the process correctly, double clicking on the variables as you choose them.

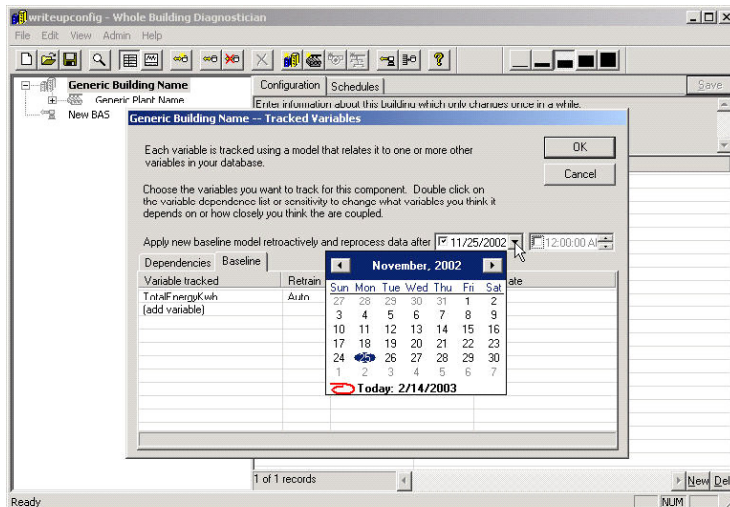
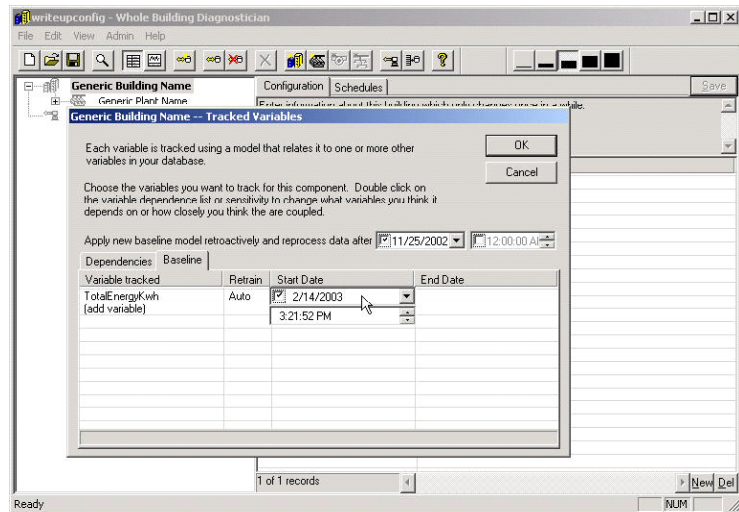


41. After you have entered all variables to be tracked, the variables on which their models will depend, and the resolution (sensitivity), select the **Baseline tab** in the Tracked Variables window. Each variable tracked will need a retrain value of either Never, Auto, or Ask. “Yes” although entered as the default value, is not a valid choice. You must change the value to one of the other options. To change the value,



double click on the retrain cell for the variable you wish to modify. A new value will appear in the cell. Continue double clicking on that cell until the option you want appears. Typically, Auto is the choice used.

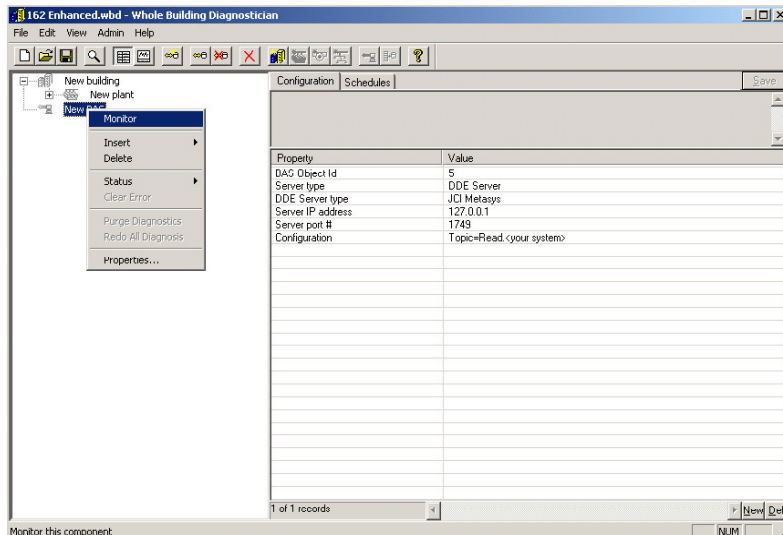
42. Next, input the **Start date** and **End date** for the model. This would be the date (and time) for which you have or plan to collect data for the dependent and independent variables to use as the baseline data. If this is an initial setup and you do not have access to historical data, leave the **End Date** blank. Repeat steps 41 and 42 for all of the tracked variables.



43. If this is an initial installation, set the “**Apply new baseline model retroactively and reprocess data after**” to today’s date. If you have historical data, set it to the appropriate date that would be valid for your model. To change that date, click on the arrow on the right side of the date box. A calendar box will pop up. Use the left/right arrows on the calendar box to navigate to the appropriate month/year and select the date by clicking on it. The time can be modified by selecting the hour, minute, seconds, and AM-PM sections of the time display, one at a time, and then using the up and down arrows on the right side to adjust the value.

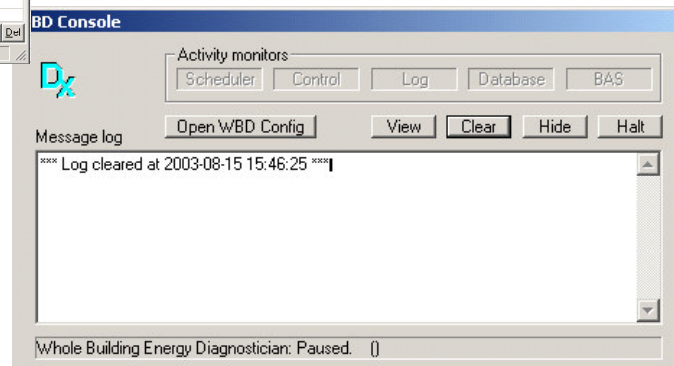
After making those changes select **OK**. You are now ready to initiate data collection and building energy diagnostics.

Starting Data Collection

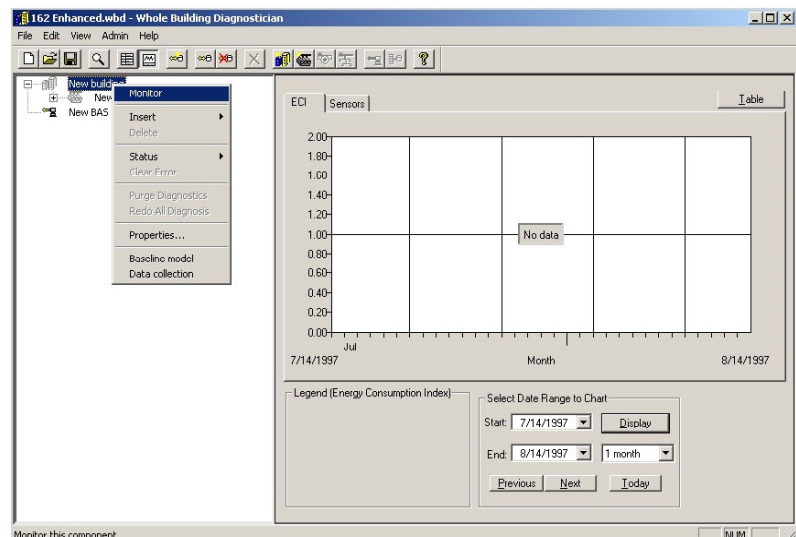


44. To turn on data collection, highlight the network name in the tree. For our example, the network is “New BAS.” Right-mouse click on network name and click on **Monitor**. This must be done by an administrative user.

45. After the network is monitored, the window at right, referred to as the WBD Console, will appear. Notice that a red “D_x” will appear in the lower right-hand corner of your Windows task bar. This designates that data collection is active. From the console you may *open a WBD configuration*, *view data collection text file messages*, *clear the console messages*, *hide the console window*, or *halt the data collection*. If the administrative user hides the console, double-clicking on the D_x icon in the lower right corner will restore the console for viewing.



46. Whole-Building Energy diagnostic results will not be meaningful for 2 to 3 weeks because the system must first develop initial models for estimating expected energy consumption. After this initial data collection period, diagnostic results may be viewed by “monitoring” the building



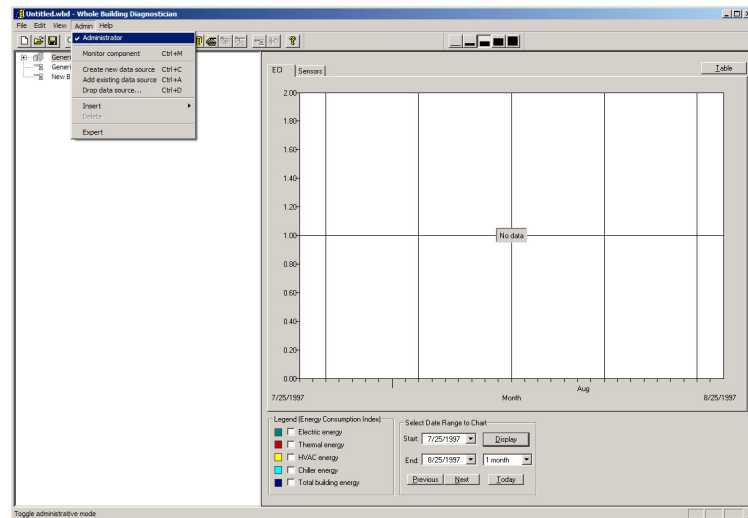
name on the tree. To view the results, right click on the building name (“Generic Building Name” in the figure) to reveal a drop down menu and then select **Monitor**.

Diagnostic results should now be displayed in the main (right) pane. Repeat monitor other buildings in configuration.

Any user can view diagnostic results, but only administrative users can create/change configuration

software. Administrators should make sure that administrative privileges are turned off when the computer is accessible by others. To verify administrator privileges are off, click on **Administrator** in the Admin drop down menu and confirm that no check mark appears before **Administrator**.

The WBD user interface can be opened and closed without interrupting the data collection process and can be used by any level user to view diagnostic results.



view results, but administrative start/stop and the of the

Task Report for the

**Energy Efficient and Affordable Small
Commercial and Residential Buildings
Research Program**

*a Public Interest Energy Research Program
sponsored by the California Energy Commission*

**Project 2.6 - Enhancement of the Whole-
Building Diagnostician**

**Task 2.6.10 - Whole-Building Energy Enhancement
Report**

David P. Chassin
Krishnan Gowri
Teresa A. Carlon
Nathan N. Bauman

August 2003

Prepared for
Architectural Energy Corporation

Battelle Pacific Northwest Division
Richland, Washington 99352

Contents

1	Introduction to the WBE Enhancements	1
2	WBE Background	2
3	WBE Software Bugs Fixed	3
4	Methodology for Multi-Variate Whole-Building Energy Diagnostics	11
	References	13

1 Introduction to the WBE Enhancements

This document is one of a collection of reports for Project 2.6: Enhancement of the Whole-Building Diagnostician (WBD). It documents parts of the task to enhance the Whole-Building Energy (WBE) Module to support tracking a greater variety of energy variables and increasing the flexibility of the models used for normalizing values of those variables. This report summarizes the technical elements and results of the work performed. Instructions for using the WBE are provided in the *Instructions for Configuration of the Whole-Building Diagnostician Software*.

Section 2 of this report provides a brief description of the WBE and the enhancements developed under this project. Section 3 provides a table of key software bugs fixed after initially implementing the enhancements, and Section 4 provides a brief description of the method used as the basis for modeling expected energy consumption.

2 WBE Background

The WBE module tracks energy end uses at the whole-building level, specifically total building energy, electric energy, thermal energy, heating, ventilation, and air conditioning energy, and chiller energy. Analysis results are presented as an Energy Consumption Index (ECI) for each day. The ECI is the ratio of actual energy consumption to expected energy consumption. The values of expected energy consumption are generated by a model that performs statistical analysis of a baseline set of historical data collected from the building or systems. Statistical properties of the expected value are compared to the actual value to determine whether the actual measurement is significantly different. In general, the baseline model uses time of day, day of the week, outdoor-air dry-bulb temperature, and relative humidity as independent variables.

The objective of this task was to develop an enhanced WBE so that advanced users can add other independent variables, such as occupancy and plug loads, to the models. The enhanced capabilities are as follows:

- ✓ Enable the user to specify any independent variable (not just date, time, temperature and humidity) in the models
- ✓ Allow the tracking of any variable (not just whole-building thermal and electric meter readings)
- ✓ Manage the collection of data for all the variables now supported
- ✓ Enhance the user interface to support the enhanced features.

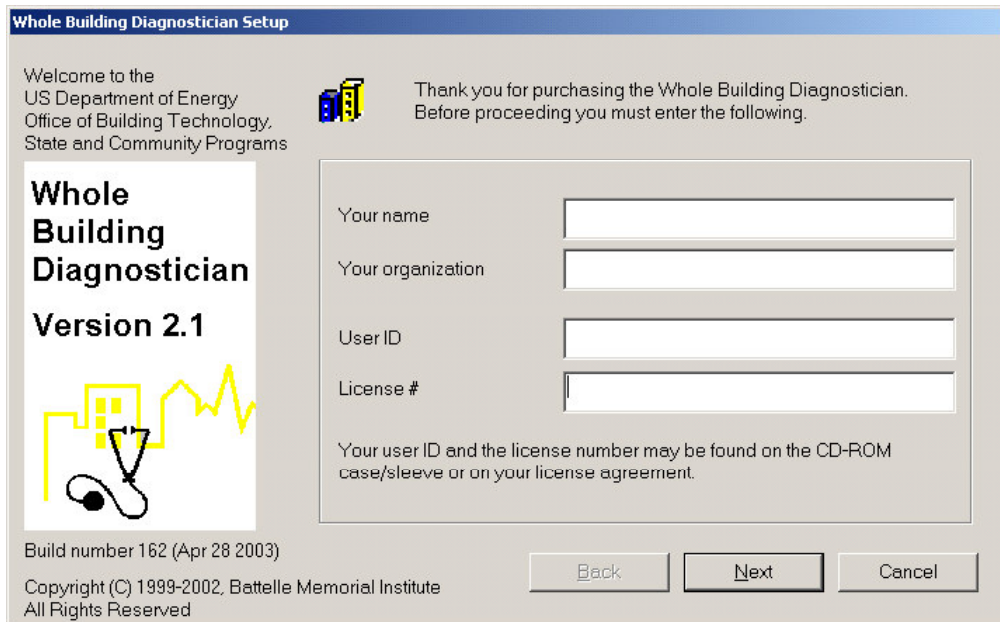
These enhancements provide a flexible tool for monitoring and diagnosing whole-building and system-level energy consumption in new and existing commercial buildings of all sizes.

3 WBE Software Bugs Fixed

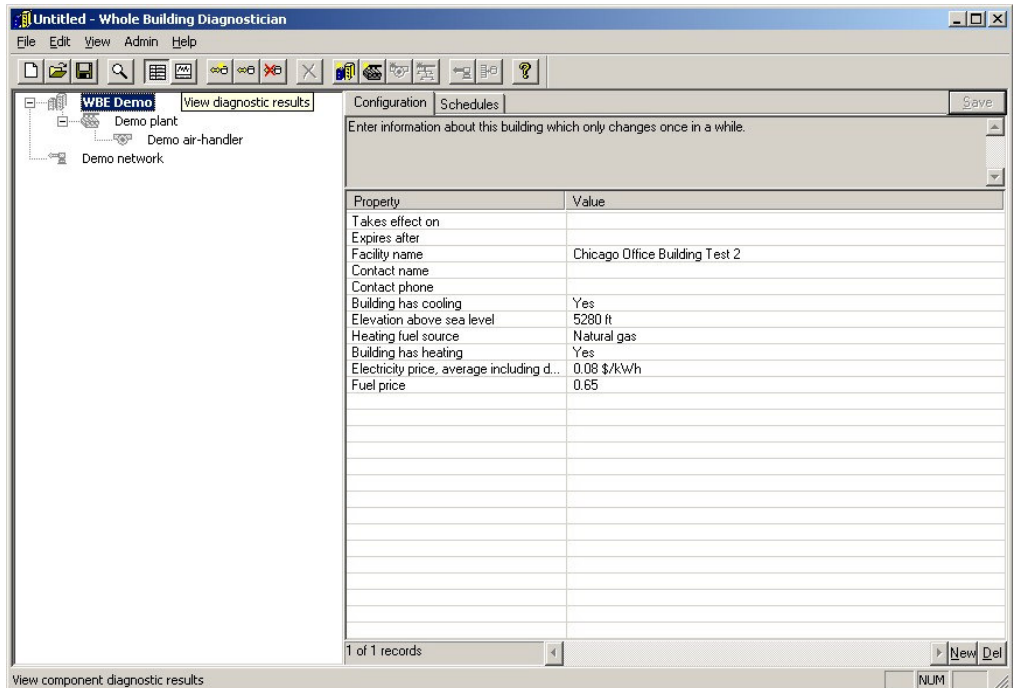
Description of Enhancement

Removed the word “Diagnostic Configuration” and replaced it with “Diagnostician Setup”.

Change in Screen Image



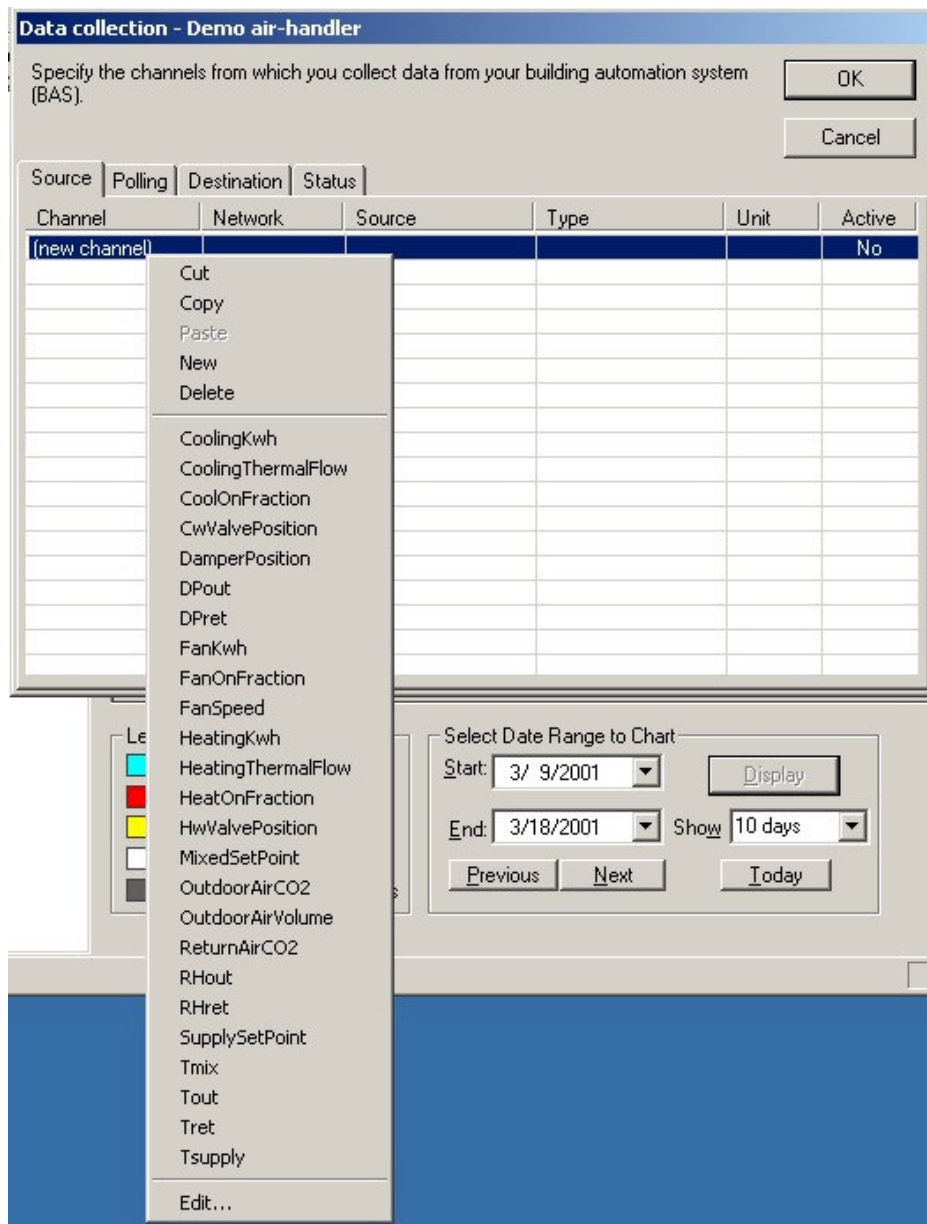
Placing your cursor over the icons on the toolbar will momentarily give you a brief description of the icon function.



Description of Enhancement

All data units will be displayed with a right-mouse click in the “new channel” box. Adding a new channel can be done by clicking “new” on the list.

Change in Screen Image



Description of Enhancement

Existing value in the configuration screens remains in the dialogue box should you decide not to change the entry. Prior to this fix, the value was disappearing if you clicked on the background white space.

Change in Screen Image

Property	Value
Schedule	1-12 1-7 0-24
Takes effect on	1-12 1-7 0-24
Expires after	Never changes Week days Week nights Weekends

Added a "Close" button to the ECI detailed problem tab.

Date	Problem	ECI	Actual	Normal range	Daily cost	Weekly cost
8/7/1997	Actual Total building energy is too high.	1.06	10775 kWh	9580 - 10542 kWh	\$41	\$285
	Actual Electric energy is too high.	1.06	10775 kWh	9580 - 10542 kWh	\$41	\$285
	Actual HVAC energy is too high.	1.12	5563 kWh	4369 - 5330 kWh	\$41	\$285
	Actual Chiller energy is too high.	1.14	3974 kWh	2963 - 3749 kWh	\$32	\$227

The configuration item of the network object is now being displayed.

Property	Value
BAS Object Id	5
Server type	DDE Server
DDE Server type	JCI Metasys
Server IP address	127.0.0.1
Server port #	1749
Configuration	Topic=Read.<your system>

Description of Enhancement

Using the data collection feature to set up data channels will no longer cause duplicates in the ChannelConfig table.

Change in Screen Image

[illegible]

Baslink is now able to reprocess raw data without manually clearing the LastPoll field in the ChannelConfig table.

No change in user interface.

Description of Enhancement

The reliability column on the Destination tab under data collection will now hold a value of 100%.

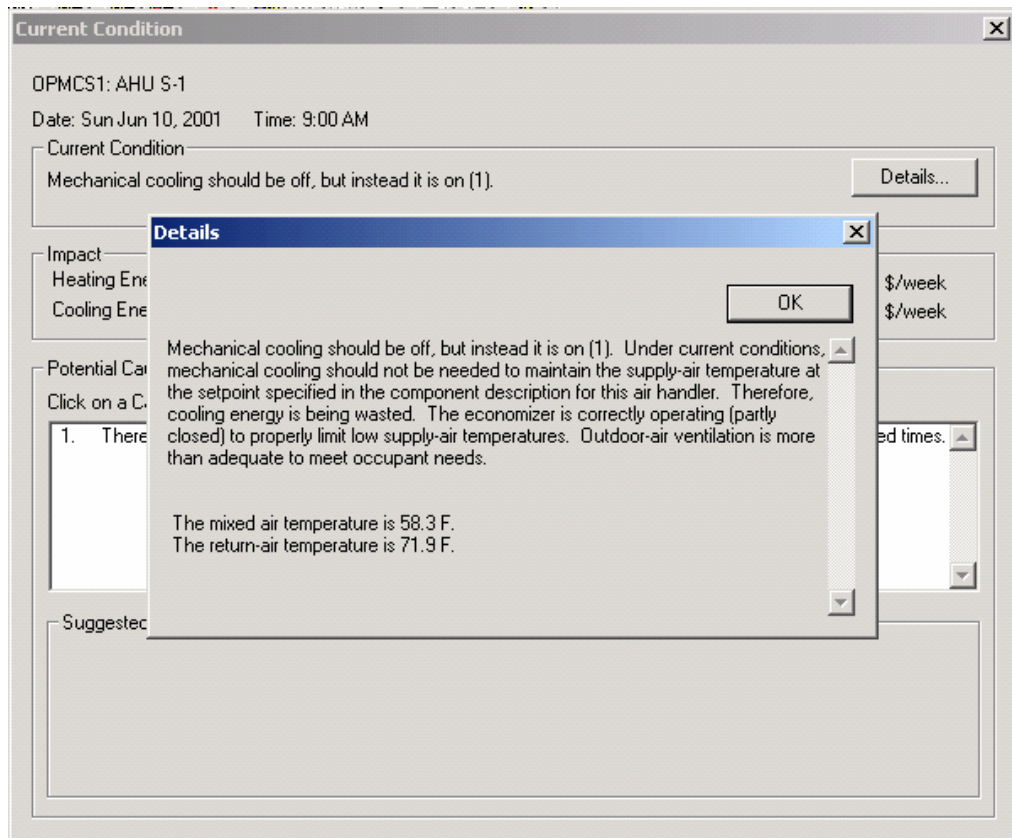
Change in Screen Image

[illegible]

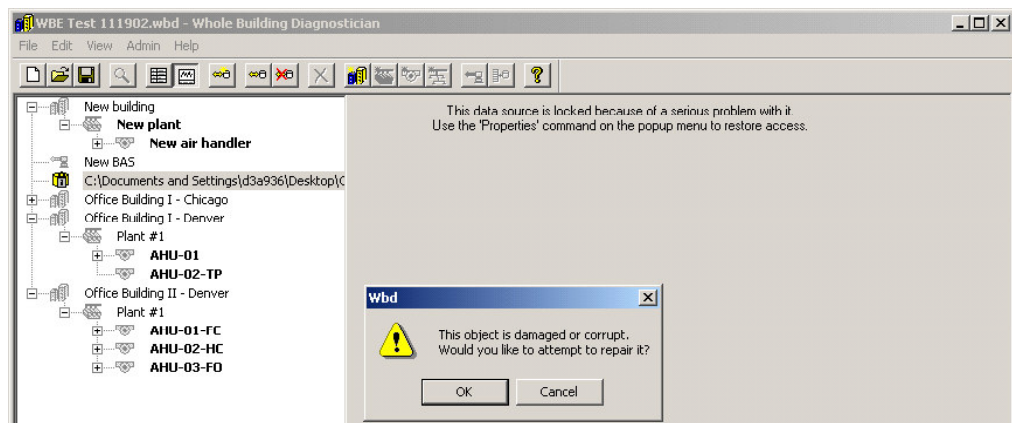
Description of Enhancement

Attempting to display a message that does a database lookup on a “null” field will not crash the WBD.

Change in Screen Image



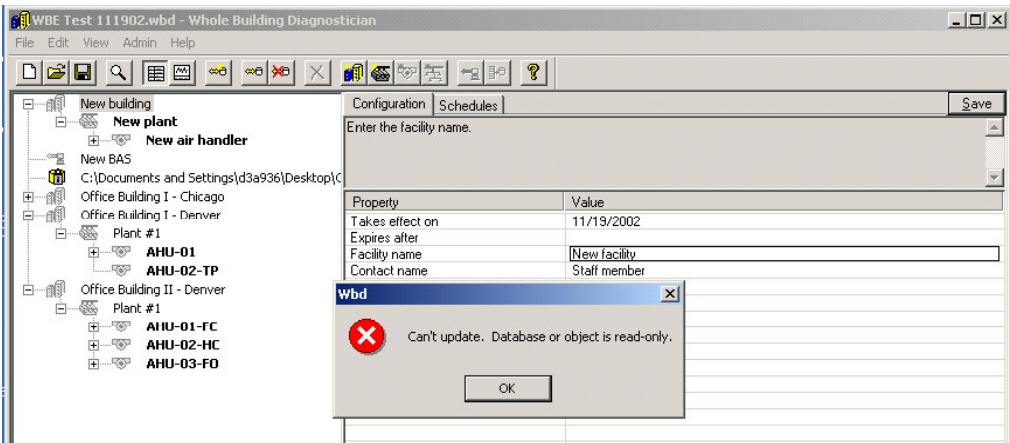
When displaying a corrupt database in the tree, the remaining objects below the corrupt database will now be displayed.



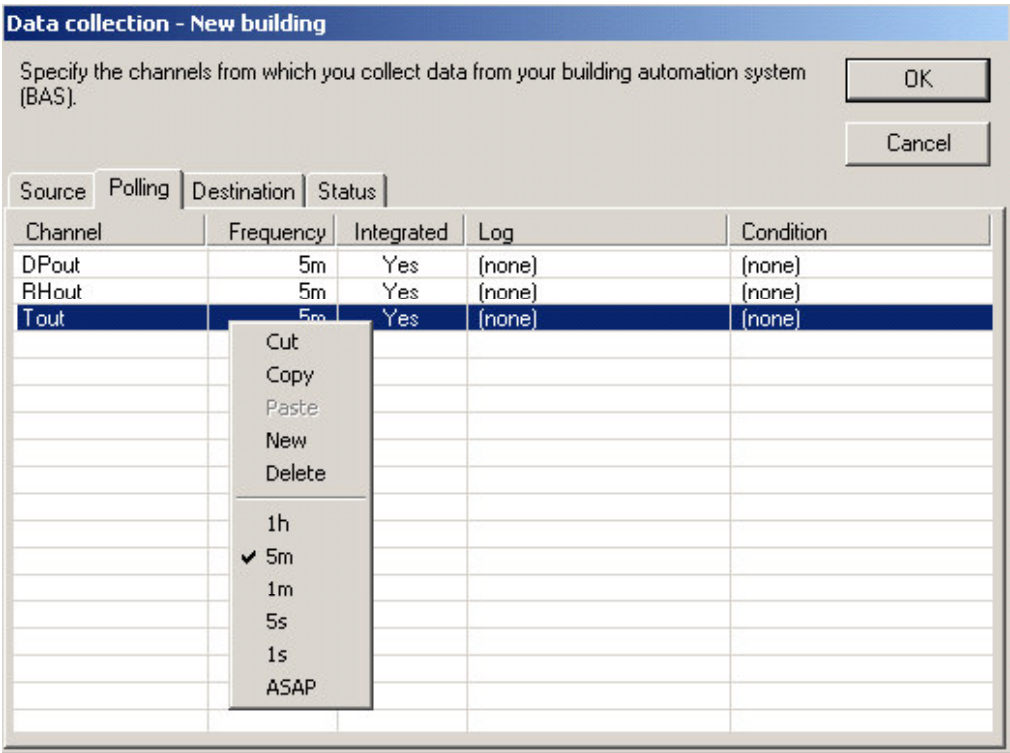
Description of Enhancement

A user now has a read-only status to view the file configuration settings. The user is unable to change any setting without being in Admin or Expert mode.

Change in Screen Image



Data collection column values no longer populate themselves back onto the list.



Description of Enhancement

The Building Automation tab now reflects the same settings as in the Data Collection Logged and Conditional properties under the Polling tab.

Change in Screen Image

[illegible]

4 Methodology for Multi-Variate Whole-Building Energy Diagnostics

Determining whether actual building energy use is as expected requires a model of building end-use energy consumption. Such a model is used to produce expected consumption against which actual consumption is compared. The result of the comparison is then used to indicate to building operators whether actual building energy usage is abnormal and requires further investigation. Several modeling techniques have been employed to produce expected energy use for a given set of conditions. This report documents the current modeling technique used in the Whole-Building Energy Diagnostician (WBE) and the changes proposed to make the modeling technique work better for buildings other than the class of light commercial and office buildings for which it was originally designed.

The ASHRAE Handbook of Fundamentals (ASHRAE 1997) specifies that a bin-method is an energy estimating technique wherein energy usage for different temperature intervals and time periods is evaluated separately. Hours of the day, days of the week, and outdoor conditions are grouped to form bins for which energy usage is calculated. For example, typical daily hour bins might be three 8-hour bins for 12 am to 8 am, 8 am to 4 pm, and 4 pm to 12 am. Temperature bins might be for 5°F increments in temperature.

For a bin-based energy model, the energy usage for each bin is calculated and multiplied by the number of hours it occurs during the year. When the results are summed over all bins, the result yields a total annual energy usage for a building.

This method is preferred over the simpler use of degree-day energy estimating because it is better at considering the variations in system efficiency in response to load variations, occupancy and outdoor conditions.

The method used by the WBE for estimating energy use in a building (whole building or partial end-use load) based on its past performance during a baseline period is called a bin method, although it is basically the reverse of the ASHRAE-type process described above. In the WBE we essentially bin the loads (instead of the hours) into bins defined by temperature, relative humidity (RH), and hour of week—a three-way split. Instead of counting hours, we essentially average the energy use in each bin. Thus, the baseline model reflects the building's or end-use's time-of day and day-of-week schedule, and the influence of outdoor temperature and relative humidity.

If we used the same size bins as in the previous example, there would be 27,216 bins (24 hours per day x 7 days per week x 18 temperature intervals x 9 relative humidity intervals). This would require data from too long a time period or take far too long to populate with hourly data to be practical.

The WBE's pseudo-bin method introduces a few significant variations on the basic concept of a bin method—hence, the term pseudo-bin. First of all, it does not pre-compute the population of loads in each bin. Instead, it uses “sliding” bins, created “on-the-fly.” For example, assume the temperature bins are 5°F-wide, and the RH bins are 10%-wide. Then, if it is 9 am on a Monday and the current temperature and relative humidity are 58°F and 61%, the WBE's baseline load estimate is the median of all the loads in the baseline period that meet the following criteria: hour of week = 33, temperature = 58°F±2.5°F and RH = 61%±5%.

Tests against field data have shown that models using bin medians produce more stable expected loads than those using bin averages, particularly when the number of observations in a bin is small or many of the loads are zero. Therefore, we use bin medians to represent expected energy consumption for conditions in each bin.

The advantage of sliding bins is that they produce a smooth energy-use trajectory as conditions change, instead of the lumpy, step-wise changes in loads that would result if you crossed the boundary from one

fixed bin to another. In addition, sliding bins require less data because the data are used for more than one bin and the bins can be somewhat wider to include more data points but without a loss in accuracy.

Overall the WBE's energy bin method does not assume a linear (or any prescribed functional) response of energy to the input variables. It is completely free to follow the empirical data without mathematical constraints. Further, like a neural-net, it ignores variables that don't explain the energy consumption's variations.

The WBE's bin method can be generalized to any variable and any number of explanatory variables. For example, many industrial loads have nothing to do with either time of day or day of week. So, those variables can be replaced with others that might be useful in explaining a load. This is what we mean by a generic pseudo-bin method--it is a varying multi-way split--purely statistical and unrelated to any *a priori* variables, such as weather.

References

ASHRAE. 1997. *1997 ASHRAE Handbook of Fundamentals (SI)*, American Society of Heating Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Georgia, p. 30.20.